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FACTS AND FACTORS OF DEVELOPMENT[1]

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Introduction

ONE of the greatest results of the doctrine of organic evolution has been the determination of man's place in nature. For many centuries it has been known that in bodily structures man is an animal —that he is born, nourished and developed, that he matures, reproduces and dies just as does the humblest animal or plant. For centuries it has been known that man belongs to that group of animals which have backbones, the vertebrates, to that class which have hair and suckle their young, the mammals, and to that order which have grasping hands, flat nails, and thoracic mammæ, the primates, which group includes also the monkeys and apes. But as long as it was supposed that every species was distinct in its origin from every other one, and that each arose by a special divine fiat, it was possible to maintain that man was absolutely distinct from the rest of the animal world, and that he had no kinship to the beasts, though undoubtedly he was made in their bodily image. But with the establishment of the doctrine of organic evolution this resemblance between man and the lower animals has come to have a new significance. The almost universal acceptance of this doctrine by scientific men, the many undoubted resemblances between man and the lower animals, and the discovery of the remains of lower types of man, real "missing links," has inevitably led to the conclusion that man also is a product of evolution, that he is a part of the great world of living things and not a being who stands apart in solitary grandeur in some isolated sphere.

But wholly aside from the doctrine of evolution, the fact that essential and fundamental resemblances exist among all kinds of organisms can not fail to impress thoughtful men. The great life processes are everywhere the same in principles, though varying greatly in details.

[1] First of the Norman W. Harris Lectures for 1914 at Northwestern University on "Heredity and Environment in the Development of Men"; to be published by the Princeton University Press.

All the general laws of life which apply to animals and plants apply also to man. This is no mere logical inference from the doctrine of evolution, but a fact which has been established by countless observations and experiments. The essential oneness of all life gives a direct human interest to all living things. If "the proper study of mankind is man," the proper study of man is the lower organisms in which life processes are reduced to their simplest terms, and where alone they may be subjected to conditions of rigid experimentation. Upon this fundamental likeness in the life processes of man and other animals is based the wonderful work in experimental medicine, which may be counted among the greatest of all the achievements of science.

The experimental study of heredity, development and evolution in forms of life below man must certainly increase our knowledge of and our control over these processes in the human race. If human heredity, development and evolution may be controlled to even a slight extent, we may expect that sooner or later the human race will be changed for the better. At least no other scheme of social betterment and race improvement can compare for thoroughness, permanency of effect, and certainty of results, with that which attempts to change the natures of men and to establish in the blood the qualities which are desired. We hear much nowadays about man's control over nature, though in no single instance has man ever changed any law or principle of nature. What man can do is to put himself into such relations to natural phenomena that he may profit by them, and all that can be done toward the improvement of the human race is to consciously apply to man those great principles of development and evolution which have been operating unknown to man through all the ages.

Phenomena of Development

One of the greatest and most far-reaching themes which has ever occupied the minds of men is the problem of development. Whether it be the development of an animal from an egg, of a race or species from a preexisting one, or of the body, mind and institutions of man, this problem is everywhere much the same in fundamental principles, and knowledge gained in one of these fields must be of value in each of the others. Ontogeny and phylogeny are not wholly distinct phenomena, but are only two aspects of the one general process of organic development. The evolution of races and of species is sufficiently rare and unfamiliar to attract much attention and serious thought; while the development of an individual is a phenomenon of such universal occurrence that it is taken as a matter of course by most people—something so evident that it seems to require no explanation; but familiarity with the fact of development does not remove the mystery which lies back of it, though it may make plain many of the processes concerned. The development of a human being, of a personality, from a germ cell is the

climax of all wonders—greater even than that involved in the evolution of a species or in the making of a world.

The fact of development is everywhere apparent; its principal steps or stages are known for thousands of animals and plants; even the precise manner of development and its factors or causes are being successfully explored. Let us briefly review some of the principal events in the development of animals, and particularly of man, and then consider some of the chief factors and processes of development. Most of our knowledge in this field is based upon a study of the development of animals below man, but enough is now known of human development to show that in all essential respects it resembles that of other animals, and that the problems of heredity and differentiation are fundamentally the same in man as in other animals.

I. Development of the Body

The entire individual—structures and functions, body and mind—develops as a single indivisible unity, but for the sake of clarity it is desirable to deal with one aspect of the individual at a time. For this reason we shall consider first the development of the body, and then the development of the mind.

1. *The Germ Cells.*—In practically all animals and plants individual development begins with the fertilization of a female sex cell, or egg, by a male sex cell, or spermatozoon. The epigram of Harvey, "Omne vivum ex ovo," has found abundant confirmation in all later studies. Both egg and spermatozoon are alive and manifest all the general properties of living things. How little this fact is appreciated by the public is shown by the repeated announcements by the newspapers that "Professor So-and-so has created life because he has made an egg develop without fertilization." An egg or a spermatozoon is as much alive as is any other cell—as characteristically alive as is the adult animal into which it develops. It is difficult to define life, as it is also to define matter, energy, electricity, or any other fundamental phenomenon, but it is possible to describe in general terms what living things are and what they do. Every living thing whatever, from the smallest and simplest microorganism to the largest and most complex animal, from the microscopic egg or spermatozoon to the adult man, manifests the following distinctive properties:—

1. It contains protoplasm, "the material basis of life," which is composed of the most complex substances known to chemistry. Protoplasm is not a homogeneous substance, but it always exists in the form of cells, which are minute masses of protoplasm composed of many distinct parts, the most important of these being the nucleus and the cytoplasm (Fig. 1). Protoplasm is therefore organized, that is, composed of many parts all of which are integrated into a single system, the cell. Higher animals and plants are composed of multitudes of cells, differing more

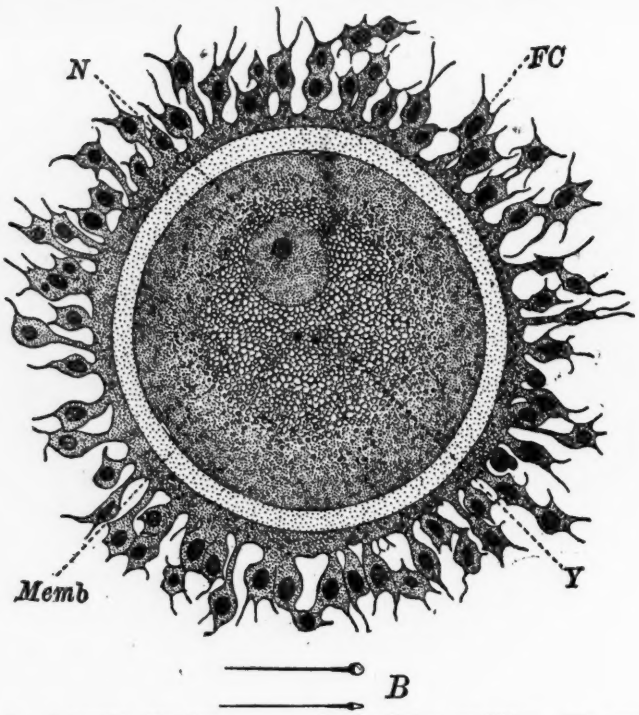


FIG. 1. A nearly ripe human ovum in the living condition. The ovum is surrounded by a series of follicle cells (*FC*) inside of which is the clear membrane (*Memb.*) and within this is the ovum proper containing yolk granules (*Y*) and a nucleus (*N*) embedded in a clear mass of protoplasm. Magnified 500 diameters (× 500). (From O. Hertwig.) *B*, two human spermatozoa drawn to about the same scale of magnification. (After G. Retzius).

or less from one another, which are bound together and integrated into a single organism. Living cells and organisms are not static structures which are fixed and stable in character, but they are systems which are undergoing continual change. They are like the river, or the whirlpool, or the flame, which are never at two consecutive moments composed of the same particles but which nevertheless maintain a constant general appearance; in short they are complex systems in dynamical equilibrium.

The principal physiological processes by which all living things maintain this equilibrium are:

2. Metabolism, or the transformation of matter and energy within the living thing, in the course of which some substances are oxidized into waste products, with the liberation of energy, while other substances are built up into protoplasm, each part of the cell converting food substances into its own particular substance by the process of assimilation.

3. Reproduction, or the capacity of organisms to give rise to new organisms, of cells to give rise to other cells, and of parts of cells to give rise to similar parts by the process of division.

4 Irritability, or the capacity of receiving and responding to im-

pinging energies, or stimuli, in a manner which is usually, but not invariably, adaptive or useful.

Both the egg and the sperm are living cells with typical cell structures and functions, but with none of the parts of the mature organism into which they may develop. But although they do not contain any of the differentiated structures and functions of the developed organism, they differ from other cells in that they are capable under suitable conditions of producing these structures and functions by the process of development or differentiation, in the course of which the general structures and functions of the germ cells are converted into the specific structures and functions of the mature animal or plant.

In both plants and animals the sex cells are fundamentally alike, though they differ greatly in appearances. The female sex cells of flowering plants are called ovules, the male cells pollen. The corresponding cells of animals are known as ova and spermatozoa. Collectively all kinds of sex cells are called gametes, and the individual formed by the union of a male and female gamete is known as a zygote, while the cell formed by the union of egg and sperm is frequently called the oosperm.

The egg cell of animals is usually spherical in form and contains more or less food substance in the form of yolk; it varies greatly in size, depending chiefly upon the quantity of yolk, from the great egg of a bird, in which the yolk, or egg proper, may be hundreds of millimeters in diameter, to the miscroscopic eggs of oysters and worms, which may be no more than a few thousandths of a millimeter in diameter. The human ovum is microscopic in size (about 0.2 mm. in diameter) but it is not smaller than is found in many other animals. It has all the characteristic parts of any egg cell, and can not be distinguished microscopically from the eggs of several other mammals, yet there is no doubt that the ova of each species differ from those of every other species, and later we shall see reasons for concluding that the ova produced by each individual are different from those produced by any other individual.

The sperm, or male gamete, is among the smallest of all cells and is usually many thousands of times smaller than the egg. In most animals, and in all vertebrates, it is an elongated, thread-like cell with an enlarged head which contains the nucleus, a smaller middle-piece, and a very long and slender tail or flagellum, by the lashing of which the spermatozoon swims forward in the jerking fashion characteristic of many monads or flagellated protozoa. In different species of animals the spermatozoa often differ in size and appearance, and there is every reason to believe that the spermatozoa of each species are peculiar in certain respects even though we may not be able to distinguish any structural differences under the microscope. The human spermatozoa closely resemble those of other primates but are still slightly different, and the conclusion is inevitable, as we shall see later, that the sperma-

tozoa as well as the ova of each individual differ slightly from those of every other individual.

2. *Fertilization.*—If a spermatozoon in its swimming comes into contact with a ripe but unfertilized egg, the head and middle-piece of the sperm sink into the egg while the tail is usually broken off and left outside. The nucleus in the head of the sperm then begins to absorb material from the egg and to grow in size and at the same time a minute granule, the centrosome, appears, either from the middle-piece or

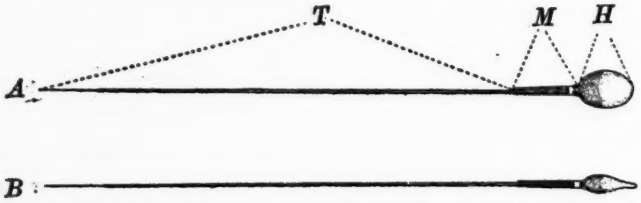


FIG. 2. TWO HUMAN SPERMATOZOA. *A*, showing the surface of the flattened head; *B*, its edge; *H*, head; *M*, middle piece; *T*, tail. (After G. Retzius.)

from the head of the sperm, and radiating lines run out from the centrosome into the substance of the egg. The sperm nucleus and centrosome then approach the egg nucleus and ultimately the two nuclei come to lie side by side. Usually when one spermatozoon has entered an egg all others are barred from entering, probably by some change in the chemical substances given out by the egg.

This union of a single spermatozoon with an egg is known as fertilization. Whereas egg cells are usually, but not invariably, incapable of development without fertilization, there begins, immediately after fertilization, a long series of transformations and differentiations of the fertilized egg which leads to the development of a complex animal—of a person. In the fusion of the egg and sperm cells a new individual, the oosperm, comes into being. The oosperm, formed by the union of the two sex cells, is really a double cell, since parts of the egg and sperm never lose their identity, and the individual which develops from this oosperm is a double being; even in the adult man this double nature, caused by the union of egg and sperm, is never lost.

In by far the larger number of animal species the oosperm, either just before or shortly after fertilization, is set free to begin its own individual existence, and in such cases it is perfectly clear that the fertilization of the egg marks the beginning of the new individual. But in practically every class of animals there are some species in which the fertilized egg is retained within the body of the mother for a varying period during which development is proceeding. In such cases it is not quite so evident that the new individual comes into being with the fertilization of the egg—rather the moment of birth or the separation from the mother is generally looked upon as the beginning of the individual existence. And yet in all cases the egg or embryo is always distinguish-

able from the body of the mother and there is no protoplasmic connection between the two. In mammals generally, including also the human species, not a strand of protoplasm, not a nerve fiber, not a blood vessel passes over from the mother to the embryo; the latter is from the moment of fertilization of the egg a distinct individual with particular individual characteristics, and this is just as true of viviparous animals

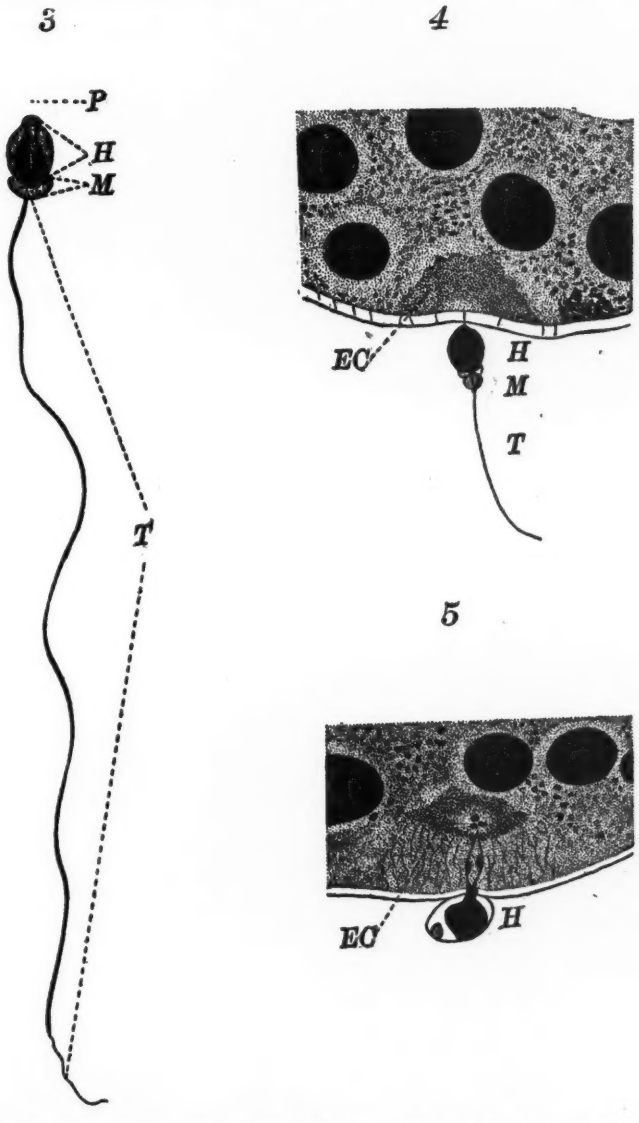
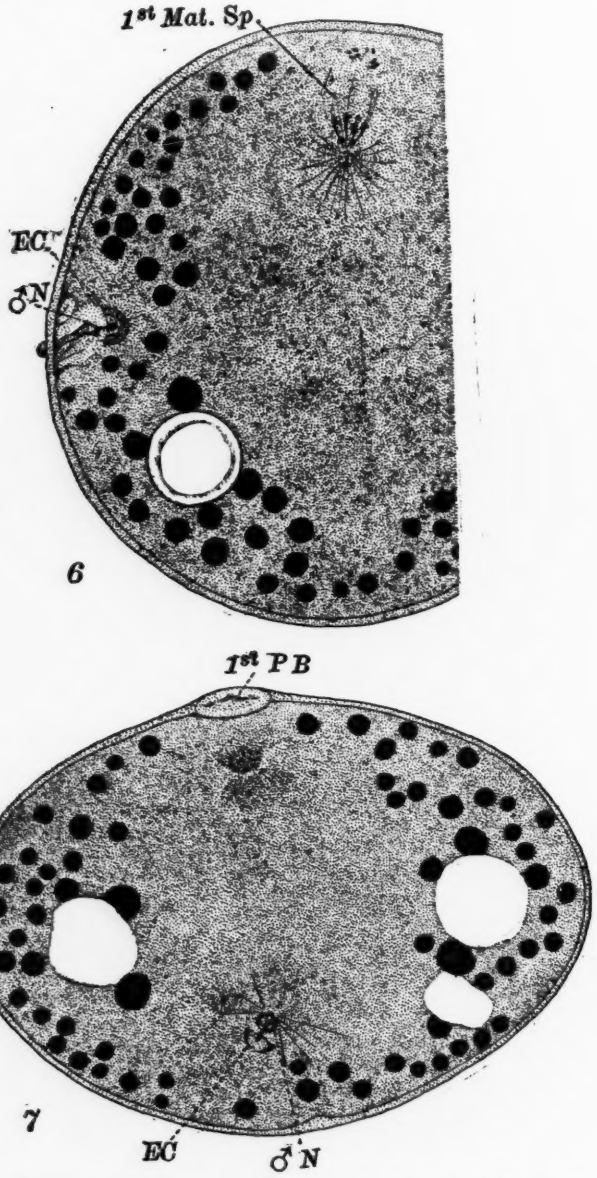


FIG. 3. ENTIRE SPERMATOZOON OF THE ANNELID *Nereis*, showing perforatorium (*P*); head (*H*); middle piece (*M*), and tail (*T*). (From F. R. Lillie.)

FIGS. 4–5. TWO STAGES IN THE ENTRANCE OF THE SPERMATOZOON INTO THE EGG OF *Nereis*. Some of the protoplasm of the egg has gathered at the point of entrance to form the entrance cone (*EC*) which, together with the sperm head, moves into the interior of the egg in later stages. The black spheres represent yolk. (From F. R. Lillie.)

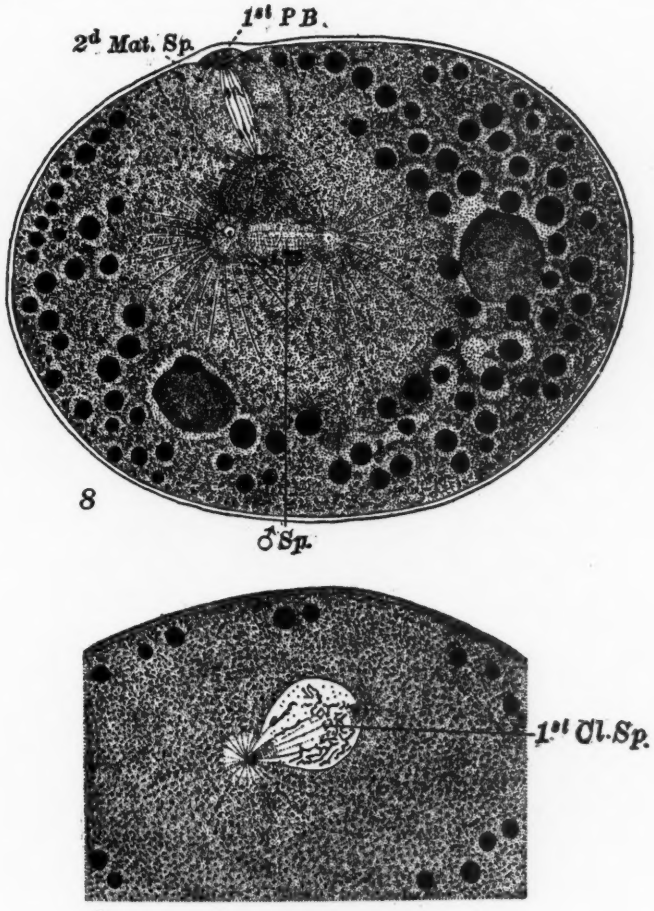
in which the egg undergoes a part of its development within the body of the mother, as it is of oviparous forms in which the eggs are laid before development begins.

The fertilized egg of a star-fish, or frog, or man is not a different individual from the adults of these forms, rather it is a star-fish, a frog, or a human being in the one-celled stage, and thereafter this new being



FIGS. 6–9. SUCCESSIVE STAGES IN THE MATURATION AND FERTILIZATION OF THE entrance cone (*EC*) and sperm nucleus (♂*N*) into the egg. Fig. 6 shows the first ma- formed by this division; Fig. 8, the second maturation spindle (*2d Mat. Sp.*) and the in the first cleavage spindle (*1st Cl. Sp.*). (From F. R. Lillie.)

maintains its own individuality. This fertilized egg fuses with no other cells, it takes into itself no living substance from without, but manufactures its own protoplasm from food substances; it receives food and oxygen from without and it gives out carbonic acid and other waste products; it is sensitive to certain alterations in the environment such as thermal, chemical and electrical changes—it is, in short, a distinct living thing, an individuality. Under proper environmental conditions this fertilized egg cell develops, step by step, without the addition of anything from without except food, water, oxygen, and such other raw materials as are necessary to the life of any adult animal, into the immensely complex body of a star-fish, a frog, or a man. At the same time from the relatively simple reactions and activities of the fertilized egg there develops, step by step, without the addition of anything from without except raw materials and environmental stimuli, the multifarious



EGG OF *Nereis*, less highly magnified than Figs. 4 and 5, showing the progress of the turation spindle of the egg (*1st Mat. Sp.*); Fig. 7, the first polar body (*1st PB*) sperm nucleus and spindle (♂*N*); Fig. 9, the division of the male and female nuclei

activities, reactions, instincts, habits, and intelligence of the mature animal.

Is not this miracle of development more wonderful than any possible miracle of creation? And yet as one watches this marvellous process by which the fertilized egg grows into the embryo, and this into the adult, each step appears relatively simple, each perceptible change is minute; but the changes are innumerable and unceasing and in the end they accomplish this miracle of transforming the fertilized egg cell into the fish, or frog, or man—a thing which would be incredible were it not for the fact that it has been seen by hundreds of observers and can be verified at any time by those who will take the trouble to study the process for themselves.

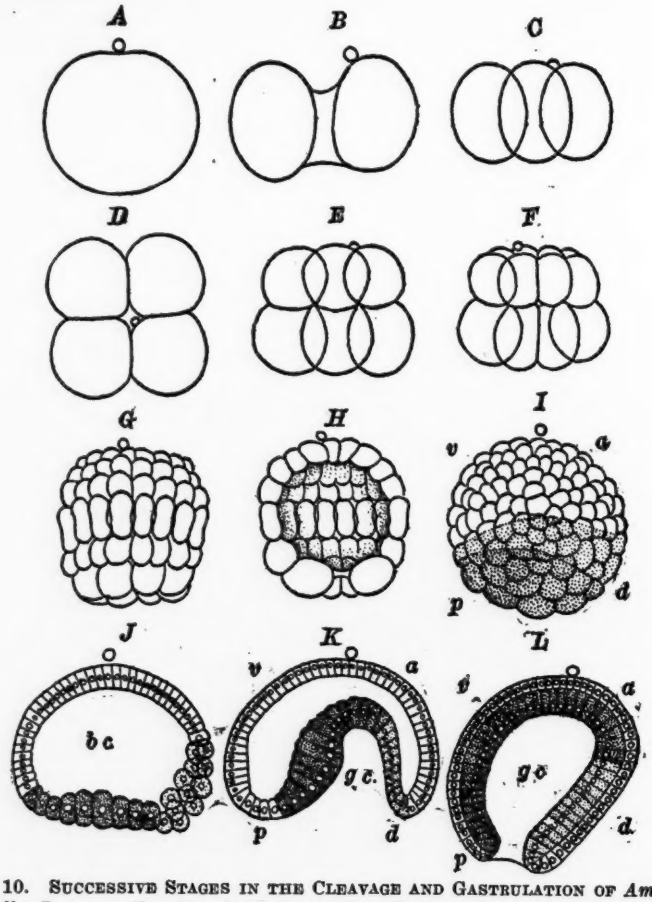


FIG. 10. SUCCESSIVE STAGES IN THE CLEAVAGE AND GASTRULATION OF *Amphioxus*. *A*, one cell; *B*, two cells; *C* and *D*, four cells; *E*, eight cells; *F*, sixteen cells; *G*, blastula stage of about ninety-six cells; *H*, section through the same showing the cleavage cavity; *I*, blastula seen from the left side showing three zones of cells, viz., an upper clear zone of ectoderm, a middle (faintly shaded) zone of mesoderm and a lower (deeply shaded) zone of entoderm cells; *J*, section through the same showing these three types of cells; *K* and *L*, successive stages in the gastrulation; cells indicated as in the preceding figure. In all figures except *D* the polar body is shown at the upper pole. Figs. *A–H* after Hatschek; Figs. *I–L* after Korschelt and Heider and Cerfontain. *a*, anterior; *p*, posterior; *v*, ventral; *d*, dorsal; *bc*, blastocœl; *gc*, gastrocœl.

3. *Cleavage.*—When the two germ nuclei (egg nucleus and sperm nucleus) have come into contact after the fertilization of the egg they divide by a complicated process known as mitosis, or indirect nuclear division (Fig. 9). The centrosome, which usually accompanies the sperm nucleus in its passage through the egg, divides and forms a spindle-shaped figure with astral radiations at its two poles (Figs. 7, 8). The chromatin, or stainable substance, of the nucleus, takes the form of threads, the chromosomes (Fig. 9), of which there is a constant number for each species of animal and plant. Each chromosome then splits lengthwise, its two halves moving to opposite ends of the spindle, in which position the daughter chromosomes fuse together to form the daughter nuclei. In this way the chromatin of the egg and sperm nuclei is exactly halved.

After the germ nuclei have divided in this manner the entire egg divides by a process of constriction into two cells (Figs, 10, 28). This is the beginning of a long series of cell divisions, each of them essentially like the first, by which the egg is subdivided successively into a constantly increasing number of cells. During the earlier divisions there

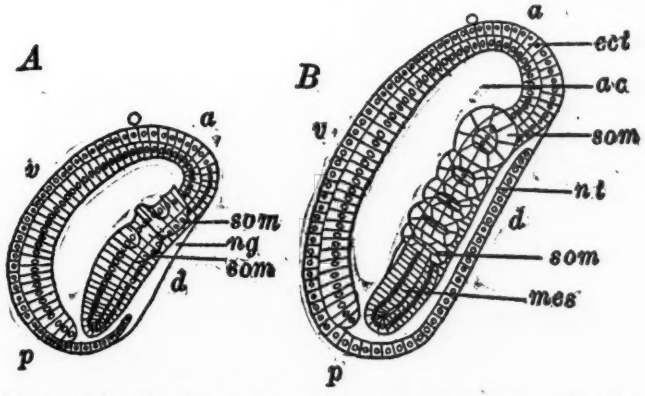


FIG. 11, *A* and *B*. TWO LATER STAGES IN THE DEVELOPMENT OF *Amphioxus*, showing the elongation of the embryo in the antero-posterior axis (*a p*), and formation of the somites (*som*); neural groove (*ng*) and neural tube (*nt*); *ect*, ectoderm; *ent*, entoderm; *mes*, mesoderm; *ac*, alimentary canal. (After Hatschek.)

is little or no increase in the volume of the egg, consequently successive generations of cells continually grow smaller (Figs. 10, 13, 14, *A*). This process is known as the cleavage of the egg, and by it the egg is not only split up into a considerable number of small cells, but a much more important result is that the different kinds of protoplasm in the egg become isolated in different cleavage cells, so that these substances can no longer freely commingle. The cleavage cells, in short, come to contain different kinds of stubstance, and thus to differ from one another. The differentiations of the cleavage cells appear much earlier in some forms than in others, but in all cases such differentiations appear during cleavage.

4. *Embryogeny.*—From this stage onward the course of development

differs in different classes of animals to such an extent that it is difficult to formulate any general description which will apply to all of them. Usually the many cleavage cells form a hollow sphere, the blastula (Fig. 10, *K*), and this in turn becomes a gastrula (Fig. 10, *L, M*), in which at first two, and later three, groups or layers of cells may be recognized; the outer layer, which is formed from cells nearest the animal pole of the egg, is the ectoderm; the inner layer, or entoderm, is formed from cells nearest the vegetative pole; a middle layer, or group of cells, the mesoderm, is formed from cleavage cells which in vertebrates lie between the animal and vegetative poles.

5. *Organogeny.*—By further differentiation of the cells of these layers and by dissimilar growth and folding of the layers themselves the various organs of the embryo begin to appear. From the ectoderm is formed the outer layer of the skin and the nervous system; from the entoderm arises the lining of the alimentary canal and its outgrowths; from the mesoderm comes, in whole or in part, the skeletal, muscular, vascular, excretory, and reproductive systems. In vertebrates the nervous system appears as a plate of rather large ectoderm cells (Fig. 12);

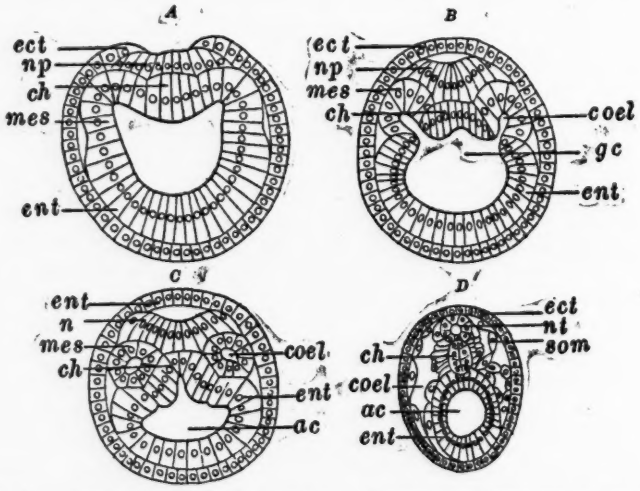


FIG. 12. CROSS SECTION OF *Amphioxus* LARVAE IN SUCCESSIVE STAGES OF DEVELOPMENT. *A*, through a larva similar to 11*A*; *B* and *C*, of a larva similar to 11*B*; *D*, of a still older larva; *ect*, ectoderm; *ent*, entoderm; *mes*, mesoderm; *ch*, notochord; *np*, neural plate; *gc*, gastrocœl; *ac*, alimentary canal; *cœl*, cœlom.

this plate rolls up at its sides to form a groove (Fig. 12) and then a tube (Fig. 12); and by enlargement of certain portions of this tube and by foldings and thickenings of its walls the brain and spinal cord are formed (Figs. 12, 15, *C, D*). The retina or sensory portion of the eye is formed as an outgrowth from the fore part of the brain (Fig. 15, *D*); the sensory portion of the ear comes from a cup-shaped depression of the superficial ectoderm which covers the hinder portion of the head (Fig. 15, *E* and *F*). The back bone begins to appear as a delicate cellu-

lar rod (Fig. 12, *ch*), which then in higher vertebrates becomes surrounded successively by a fibrous, a cartilaginous, and a bony sheath. And so one might go on with a description of all the organs of the body,

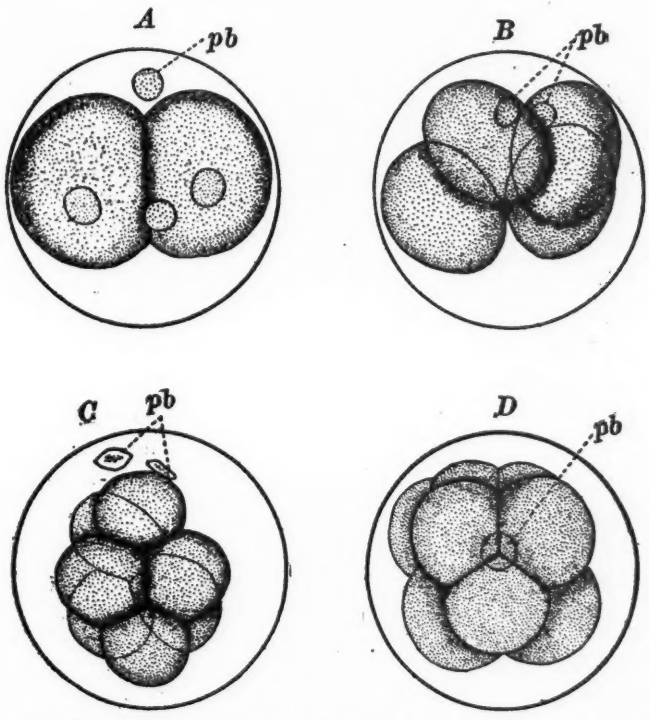


FIG. 13. FOUR CLEAVAGE STAGES OF THE SHEEP; *pb*, polar bodies. (After Assheton.)

each of which begins as a relatively simple group or layer of cells, which gradually become more complicated by a process of growth and differentiation, until these various embryonic organs assume more and more the mature form.

6. *Oviparity and Viviparity.*—This very brief and general statement of the manner of embryonic development applies to all vertebrates, man included. There are many special features of human development which are treated at length in works on embryology, but which need not detain us here since they do not affect the general principles of development already outlined. In one regard the development of the human being or of any mammal is apparently very different from that of a bird or frog or fish, viz., in the fact that in the former the embryonic development takes place within the body of the mother whereas in the latter the eggs are laid before or soon after fertilization. In man, after the cleavage of the egg, a hollow vesicle is formed, which becomes attached to the uterine walls by means of processes or villi which grow out from it (Fig. 14, *D, E, F*) while only a small portion of the vesicle becomes transformed into the embryo. There is thus established a connection between the

embryo and the uterine walls through which nutriment is absorbed by the embryo. And yet this difference is not a fundamental one for in different animals there are all stages of transition between these two modes of development. While in most fishes, amphibians and reptiles

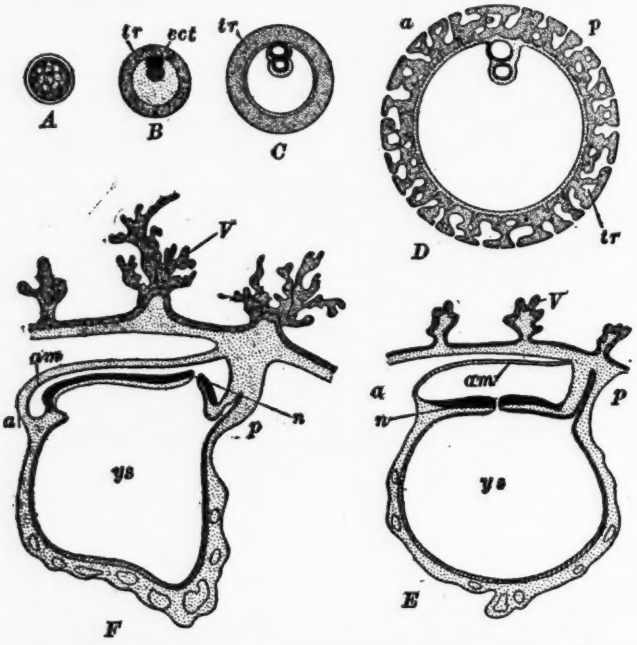


FIG. 14. DIAGRAMS SHOWING THE EARLY DEVELOPMENT OF THE HUMAN OOSPERM. *A*, cleavage stage which has just come into the uterus; *B* and *C*, blastodermic vesicles embedded in the mucous membrane of the uterus; *D*, *E* and *F*, longitudinal sections of later stages, the anterior and posterior poles being marked by the axis *a p*. In *C* cavities have appeared in the ectoderm, entoderm and mesoderm. *D*, villi forming from the trophoblast (nutritive layer, *tr*); black indicates ectoderm (*ect*); oblique lines, entoderm; few stipples, mesoderm; *V*, villi; *am*, amnion; *ys*, yolk sac; *n*, neurenteric canal (×25). (From Keibel.)

the eggs are laid at the beginning of development and are free and independent during the whole course of ontogeny, there are certain species in each of these classes in which the development takes place within the body of the mother. Even in birds a portion of the development takes place within the body of the female before the eggs are laid, and there are mammals (monotremes, marsupials) in which the young are born in a very early and imperfect condition. These facts indicate that there is no fundamental difference between oviparity and viviparity. In the latter the union between the embryo and the mother is a nutritive but not a protoplasmic one. Blood plasma passes from one to the other by a process of soakage, and the only material influences which can affect the developing embryo are such as may be conveyed through the blood plasma and are chiefly nutritive in character. Careful studies have shown that supposed "maternal impressions" of the physical, mental, or emotional conditions of the mother upon the unborn child have no exist-

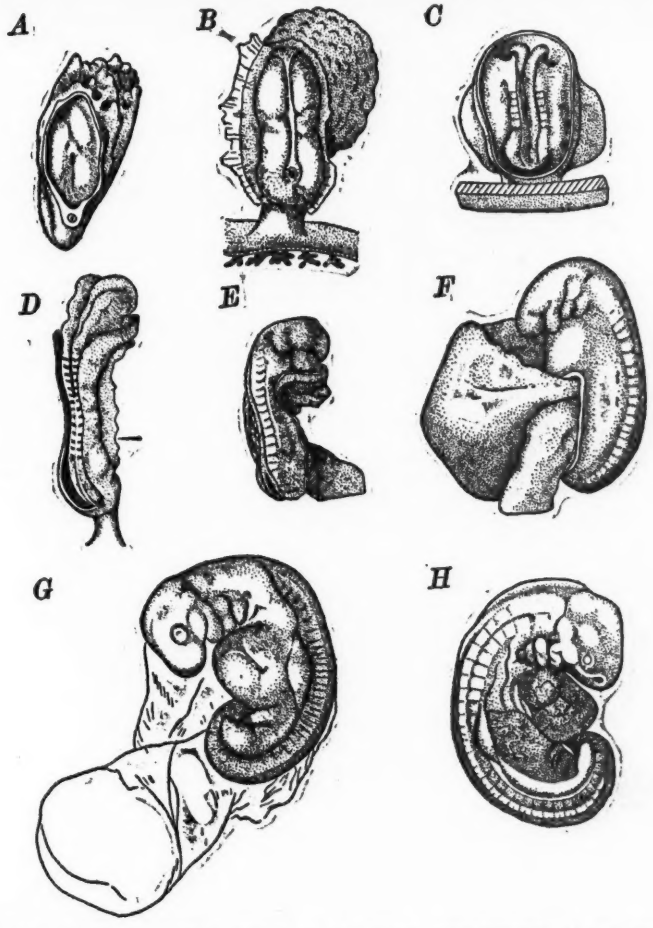


FIG. 15. *A–H*, successive stages in the early development of the human embryo. *A*, blastodermic vesicle showing primitive axis in embryonic area; age unknown. *B*, blastodermic vesicle attached to uterine wall at the posterior pole, showing neural groove; age unknown. *C*, later stage in which the neural folds are closing and five pairs of somites have appeared; age, ten to fourteen days. *D*, stage of fourteen somites showing enlargements of the neural folds at the anterior end which will form the brain; age, fourteen to sixteen days. *E* and *F* later stages, the latter with twenty-three somites and three visceral clefts. The ear shows as a depression at the dorsal angle of the second cleft. *G*, embryo of thirty-five somites showing eye, branchial arches and limb buds. *H*, embryo of thirty-six somites showing nasal pit, eye, branchial arches and clefts, limb buds and heart. (After Keibel.)

ence in fact, except in so far as the quality of the mother's blood may be changed and may affect the child. At no time, whether before or after birth, is the mother more than nurse to the child. Hereditary influences are transmitted only through the egg cell and the sperm cell and these influences are not affected by intra-uterine development. The principles of heredity and development are the same in oviparous and in viviparous animals—in fish, frogs, birds and men.

Summary.—This is a very brief and incomplete statement of some of the important stages or phases of the development of the body of man or of any other vertebrate. In all cases development begins with the

fertilized egg which contains none of the structures of the developed animal, though it may exhibit the polarity and symmetry of the adult and may also contain specific kinds of protoplasm which will give rise to specific tissues or organs of the adult. From this egg cell arise by division many cells which differ from one another more and more as development proceeds, until finally the adult animal results. A specific type of development is due to a specific organization of the germ cells with which development begins, but the earlier differentiations of the egg are relatively few and simple as compared with the bewildering complexities of the adult, and the best way of understanding adult structures is to trace them back in development to their simpler beginnings and to study them in the process of becoming.

7. *Development of Functions.*—The development of functions goes hand in hand with the development of structures; indeed function and structure are merely different aspects of one and the same thing, namely organization. All the general functions of living things are present in

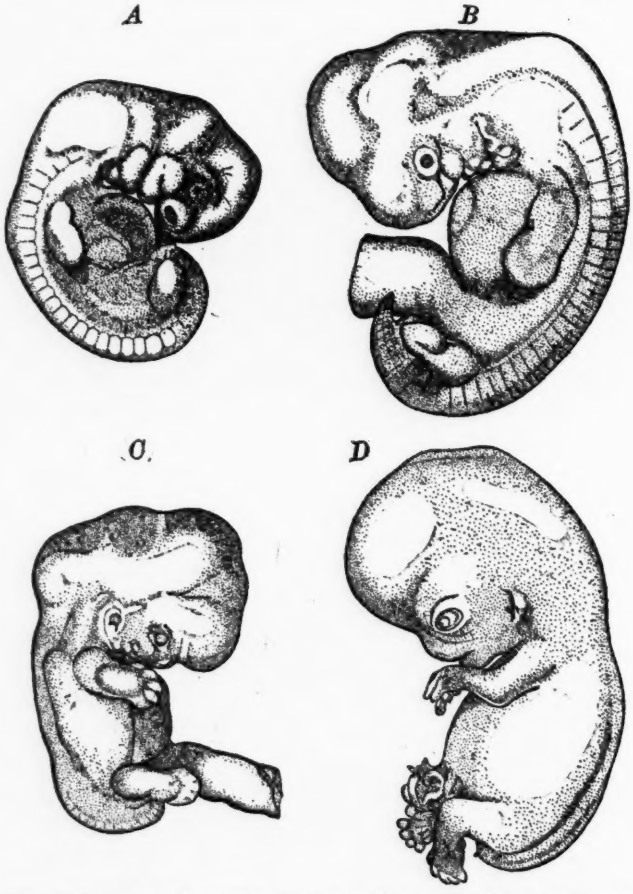


FIG. 16. *A*, human embryo of forty-two somites; ages about twenty-one days. *B*, embryo of about four weeks. *C*, still older embryo showing the beginnings of the formation of digits. *F*, embryo of about two months. (After Keibel.)

the germ cells, viz., (1) Constructive and destructive metabolism, (2) Reproduction, as shown in the division of cells and cell constituents, (3) Irritability, or the capacity of receiving and responding to stimuli. All these general functions of living things are manifested by germ cells, but as development advances each of these functions becomes more specialized, more complicated and more perfect. A cell which at an early stage was protective, locomotor and sensory in function may give rise to daughter cells in which these functions are distributed to different cells, cells which at an early stage were sensitive to many kinds of stimuli give rise to daughter cells which are especially sensitive to one particular kind of stimulus, such as vibration, light, or chemicals.

Functions develop from a generalized to a specialized condition by the process of "physiological division of labor" which accompanies morphological division of substance. But just as in the development of structures, new parts, which were not present in the germ, appear by a process of "creative synthesis," so new functions appear in the course of development, which are not merely sorted out of the general functions present at the beginning, but which are created by the interaction and synthesis of parts and functions previously present.

Much less attention has been paid to the development of functions than to the development of structures, and consequently it is not possible to describe the former with the same degree of detail as the latter. But in spite of the lack of detailed knowledge regarding the development of particular functions the general fact of such development is well established. To what extent structures may modify functions or functions structures, in the course of development, is a problem which has been much discussed, and upon the answer to which the fate of certain important theories, for example Lamarckism, depends; but this problem can be solved only by thorough-going experimental and analytical work. In the meantime it seems safe to conclude that living structures and functions are inseparable and that anything which modifies one of these must of necessity modify the other also; they are merely different aspects of organization, and are dealt with separately by the morphologists and physiologists only as a matter of convenience. At the same time there can be no doubt that minute changes of function can frequently be detected where no corresponding change of structure can be seen, but this shows only that physiological tests may be more delicate than morphological ones. In certain lines of modern biological work, such as bacteriology, cytology, genetics, many functional distinctions are recognizable between organisms which are morphologically indistinguishable. But this does not signify that functional changes precede structural ones, but only that the latter are more difficult to see than the former. For every change of function it is probable that an "unlimited microscopist" could discover a corresponding change of structure.

 (*To be concluded.*)

THE STRUGGLE FOR EQUALITY IN THE UNITED STATES

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VII

The Current Trend of Affairs

NO one in this generation has expressed the idealism of the American people as well as Mr. Roosevelt in his best moments. Speaking at Jamestown, Virginia, he said:

> The corner stone of the Republic lies in our treating each man on his worth as a man, paying no heed to his creed, his birthplace or his occupation, asking not whether he is rich or poor, whether he labors with head or hand; asking only whether he acts decently and honorably in the various relations of his life, whether he behaves well to his family, to his neighbors, to the state.

In the pursuit of this ideal, the present era of reform is beset with five difficulties. The first is the difficulty that arises from flattering the intelligence of the common man. A political order in which every man has one vote irrespective of his intelligence encourages the erroneous idea that one man knows as much as another, and makes the employment of the scientific expert appear to be a waste of the public money. Many a man who has clearly demonstrated his incapacity to manage his own affairs feels entirely competent to run the much more complicated affairs of the state and the nation.

> Nothing pleases the average mortal more than an assurance that his abilities would have qualified him to do something else much better. It gives him such a comfortable sense of completeness and versatility. Convince a curate that he would have made a capital buccaneer, and he will break most of the commandments for you. A man of science, persuaded that his first-rate abilities for the practical work of the world are wasted for lack of outlet, is as wax in the hands of the persuader.[1]

The second is the difficulty of distinguishing between reformers that are genuine and those that are fakes. According to scriptural writ, "Not every one that saith unto me, Lord, Lord, shall enter into the kingdom of heaven." Neither is every measure labeled "progressive" necessarily what it pretends to be. When some profess to be conservatives and others profess to be progressives, it is difficult enough to tell which is which, but when practically every one claims to be a reformer it is doubly difficult to draw the line between the quack nostrums of pretenders and well-meaning but unbalanced reformers, on the one hand,

[1] Hartley Withers, *op. cit.*, p. 66.

and on the other hand, the specifics of those who not only have the cause of society at heart but whose judgments are sure.

The third difficulty is the perplexing problem of determining just how far the self-interest of the individual is consistent with the general good. How much shall freedom of contract be abridged? How much social control shall be exerted over the individual in other directions? How far shall combinations of labor and capital be permitted to go in carrying out their purposes? Amid the complex conditions of modern life, these questions are more difficult to answer than ever before. It is all clear enough that restrictions here and there upon the liberty of the individual make for the greater liberty of the whole. Without some restrictions there would be nothing to arrest the hand of the social marauder. But then again individual initiative has been the great factor in human progress. Few things have done as much to advance mankind from the age of stone to the age of steel. If the individual is put in leading strings, our civilization may become stagnant. Not to push social restraint far enough is to invite anarchy. Selfishness is at once the thing that makes for progress and makes the attainment of perfection impossible. Just where is the point to curb it so as to secure the good without the evil that it works?

A fourth difficulty is the danger of insisting too little upon the fundamental principles of right conduct. Men do not do good because their hearts are evil is an old saying still worthy of belief. The primary need of every man is the reformation of his own life. It is well enough at times to protest against the wrongs inflicted upon one by others. No man worth the saving will consciously permit himself to be imposed upon or taken advantage of by others. But it is still more important that those who protest see to it that their own hearts conform to what is right and true and of good report. Those who demand justice should see to it that their own hands are clean. The first duty of organized labor is to keep itself free of such leaders as the McNamaras. The protesting spirit occasionally forgets the value of the heritage bequeathed to us by the past and the fact that there is more of good than of evil in the world. It at times runs dangerously near the point of revolt, as in some of the doctrines openly proclaimed by the militant branch of the Industrial Workers of the World. "I am come not to destroy, but to fulfil" are words which should not be forgotten. There is a crying need for more of the law-abiding spirit, for more men of high principle and of a staunch adherence to the right because it is the right.

A fifth difficulty is the tendency of the masterful element in human nature to run to extremes. The desire for domination is strong. The fighting instinct is covered with a thin veneer. An overbearing spirit is sometimes not far removed from the spirit of fair play. The craving for distinction within moderation is a wholesome desire, but snobbish-

ness is thoroughly reprehensible. Ancestral pride is sometimes carried to this extreme. There is a proneness to regard foreigners as inferiors. Every community beyond the frontier stage has its social cliques. Shopgirls sometimes refuse to fraternize at dances with domestic servants. The work of the latter is commonly regarded as menial. The privilege of exclusiveness is one of the things paid for in Pullman cars. Social precedence is with some the main thing in life. Some rich heiresses make marriage with the titled nobility of Europe their chief ambition.

> No people ever displayed the passion for inequality more greedily than we. One builds a yacht, and if he can dine an English prince at the Cowes races, or entice the German Emperor on board at Kiel, this single breath of royal atmosphere at once endows the enterprising host with the rarest social privileges at home. Every circle breaks at the touch of the king's hand.[2]

The white man loves to lord it over the black man. In some states, many whites are exempt from the educational or property qualifications to which the negro is subject. The railway, hotel and educational facilities provided for the colored race are frequently greatly inferior to those provided for the white race. The person of negro descent is greatly circumscribed in his opportunity to earn a living. In Syracuse, Ohio, a negro is not permitted to stay over night. Some churches have been rent asunder over the question of admitting a negro to membership. It is with great difficulty that a negro can buy property in many communities. The average white man may contribute to save the soul of the black man in Africa, but he does not care to have a negro who is not his servant reside in the same block. This attitude is often as marked among the descendants of abolitionists as among any other class. To call a white person a negro in some states renders one liable to a suit for damages.[3]

I

The present era of reform has made few serious mistakes in meeting the foregoing difficulties. It has reduced passenger fares and freight rates in some instances without due consideration. It has blundered more or less in trying to solve the trust problem. In many states it has not taken the first steps toward preventing the feeble-minded from polluting the race at its source. It has not addressed itself seriously enough to the solution of the race problem. "I will permit no man to injure me by making me hate him," Booker T. Washington once remarked. The present era has made little progress toward this lofty ideal. Perhaps the most ominous mistake has been the increasing expenditures for militarism including pensions. The competitive building of armaments has become a crying evil.

[2] John Graham Brooks, "The Social Unrest," p. 235.

[3] Gilbert Thomas Stephenson, "Race Distinctions in American Law," *passim;* Frank U. Quillan, "The Color Line in Ohio," *passim.*

In the main, however, the course of events has been so moderate as to attract and not to repel adherents. There is no evidence that the country is growing less radical, or that it is tiring of reform. Probably there has been no decade in the country's history during which humanitarian measures have scored so many victories as during the last ten years. Hypocrisy has been mercilessly unmasked. One stronghold of privilege after another has been assaulted. Conduct once supposed to concern no one but the individual has been seen to have a public aspect, and some of the points at which the self-interest of the individual is inconsistent with the public welfare have been noted and a measure of collective control has been imposed. The public has become more exacting in the demands which it makes upon its servants. There is a quickening influence felt in nearly every direction. The man absorbed in business and the closet philosopher are waking up to the claims of public affairs, and are contesting the supremacy of those who have hitherto run our politics. There is a growing realization that we have had the forms without the substance of a real democracy. It is not so much statutory enactments as the general atmosphere of criticism in which the ordinary man lives and works that is making for higher standards of private and public conduct. The discriminating character of the times nowhere appears to better advantage than in the readiness with which sham reformers and their works are detected and rejected. Most men are progressive in spots and the public is showing the good sense necessary to distinguish between the respects in which those who profess to lead it face the future and those respects in which they face the past. The subsidized press has lost much of its influence. It is the critical attitude of the age that is so full of promise for the future.

A notable change in public opinion has taken place since 1896. At that time the man successful in gaining public office stood primarily for an ultra-individualism and for upholding property rights. The prevailing view was that a man acted in consonance with the public interest in securing the kind of a tariff or franchise that he wanted. This idea is to-day discredited. The emphasis has shifted somewhat from business success to the broader interests of mankind. Society has become less complacent with unwholesome conditions. It is more generally understood that sweat-shops, unsanitary tenements and unduly long hours of labor threaten the well-being of the public at large as well as that of the victims immediately involved. An awakened people is striving to control its political institutions. Moreover, business and politics are such close bed-fellows that the improvement in the latter reflects the change for the better that has taken place in the former.

The forward movement of recent years has not won its triumphs without a fight. Nearly every inch of the ground has been contested by skilled and often opulent adversaries. The vested interests affected

have opposed the spirit of progress for the same reason that the silversmiths dependent upon the votaries of Diana for their living and prosperity arrayed themselves against the preaching of Paul. Nor is this surprising. Those whose pockets are threatened by any proposed reform naturally try to get off with as little loss as possible. In addition to the opposition offered by vested interests, that due to the inertia of society and to impracticable reformers has had to be met and overcome. The indifference of many of the intelligent and respectable is one of the greatest barriers to progress. The obstacles that have been successfully encountered and overcome inspire the hope that the spirit of the age is moving in the right direction.

The world-wide character of the present era of discontent strengthens and confirms this hope. In England, Germany, France and other nations there is a forward movement that has much in common. In many of the more backward countries, the suffrage is being broadened and the people are playing a more influential part in governmental affairs. The fact that personal liberty calls for more interference on the part of the state is quite generally recognized. It is not the old-time marauder who waylays his victim with a club against whom protection is needed so much as the superior cunning and unscrupulousness of a certain type of the modern man of affairs. In every progressive country, the community is now doing things which the common man once attended to himself. The individual is becoming more dependent upon the state to safeguard him against monopoly, foul air, impure milk, adulterated food and unsanitary plumbing, and to insure him against the contingencies of sickness, unemployment, accident and old age. The duty of protecting the individual against unduly long hours of labor and unwholesome conditions while at work, of preserving him from improper amusements in his leisure moments, and of supplying him with the educational facilities necessary to start him properly in life and to meet his mental and esthetic needs in his mature years is devolving more and more upon the state. There is a concerted movement to give the man who has been worsted in life a chance to get upon his feet and regain his self-respect. The growing density of population and its concentration in cities are socializing the production of certain things with which the individual has commonly supplied himself. Many European cities have municipalized the supply of water, light and local transportation. The Cincinnati board of health took over the ice plants of the city during the strike last summer. The federal government has established postal savings banks and a parcels-post, and government ownership and operation of the telephone, telegraph and railway are spreading throughout the world.

Another evidence that the present trend of affairs is not far amiss is that men seldom break things as they are without just cause. The

power of custom and tradition is strong. The religion or politics of most men is a birthright. The keen joy which the partisan of any cause experiences comes partly from being one of a multitude. The average man feels a sense of loss without a political party. There is an element in human nature which craves authority. Obedience is easier than disobedience. Many men instinctively crave direction. One function of dogma is to relieve people from the disagreeable necessity of doing their own thinking. The *raison d'être* of the political boss lies partly in relieving the community from a lot of trouble. The extraordinary longevity of the Roman Catholic Church indicates that it ministers to something fundamental in human nature. As James Bryce says:

> **Most men are fitter to make part of the multitude than to strive against it. Obedience is to most sweeter than independence; the Roman Catholic Church inspires in its children a stronger affection than any form of Protestantism, for she takes their souls in charge, and assures them that, with obedience, all will be well.[4]**

II

At first blush, the difficulty of solving the problems of the day seems a good argument against popular government. But second thought points to just the reverse conclusion. The frequency with which men vote according to their interests rather than according to reason makes it well to give the mass of men a voice in affairs to protect them from oppression. What state or section would be willing to entrust its interests to the remainder of the country? Likewise, what reason is there to suppose that the interests of any class will receive as much consideration if it is disfranchised as if it has the ballot? Would the Irish or the Scandinavian elements in our population receive as much political recognition if they did not have votes? Now that women vote in a number of states, there is some chance that an amendment to the federal constitution granting the ballot to women will be submitted to the legislatures of the several states. The disfranchisement of the negro in certain states has been followed by a movement to segregate the school funds. But altogether aside from this, the judgment of the untutored mind is often worth taking into account in solving social problems. When one considers the sophistry with which many men of reputed intelligence habitually deceive themselves and others upon the tariff, one feels encouraged to appeal to the good sense of the common man. The results frequently justify the appeal. What class is so well qualified by experience to know the evils of ill-ventilated workshops, dangerous machinery and unsanitary tenements as the working class? The associations of the professional man, the merchant or the large manufacturer tend to produce a class spirit that precludes any great familiarity with the common lot. The initiative for much of the legislation that has

[4] *Op. cit.*, Vol. II., p. 355.

lightened the burdens of those who toil has been supplied by organized labor. "I see no reason why the rule of the majority should be the rule of ignorance, unless they are not only ignorant but fools," remarks Professor Cooley.[5]

The sentiments of justice, liberty, truth and patriotism are especially strong among the masses. The spirit of brotherhood manifested in acts of kindness and service to those in need is more prevalent among the poor than among the rich. It was the common people in New England who carried through the Revolution. The men of wealth and standing were largely against it.[6] The Tories everywhere consisted chiefly of men of property. The masses in England "upheld abolition in the colonies and sympathized with the North in the American Struggle."[7] If we are to have a narrow suffrage, to what portion of society shall it be restricted? Shall we entrust our currency solely to the bankers or the political economists? There is no class whose mental horizon and sympathies are broad enough to control the destinies of the state. In the opinion of Thomas Wentworth Higginson, there has never been a period since the American people gained their independence when control of the nation by its highly educated men alone would not have been a calamity.[8] So unfriendly a critic of democracy as Lecky remarks:

> It has been the opinion of some of the ablest and most successful politicians of our time that, by adopting a very low suffrage, it would be possible to penetrate below the region where crochets and experiments and crude Utopias and habitual restlessness prevail, and to reach the strong, settled habits, the enduring tendencies, the deep conservative instincts of the nation.[9]

Universal suffrage in practise has worked much better than many of its opponents have predicted. The dire predictions of Macaulay in 1857 are a striking example.[10] Our "fertile and unoccupied land" is practically gone. Parts of New England are "as thickly peopled as old England." We have our "Manchesters and Birminghams." Periods of economic distress have come and gone. At times a multitude of people "has not had more than half a breakfast" or expected "more than half a dinner," but the poor have not plundered the rich, nor has civilization been saved at the price of liberty. The demagogue has asked "why anybody should be permitted to drink Champagne and to ride in a carriage, while thousands of honest folks are in want of necessaries," and yet we have not been ravished by the Huns and Vandals engendered

[5] Charles Horton Cooley, "Social Organization," p. 145.

[6] Thomas Wentworth Higginson, "The Cowardice of Culture," *Atlantic Monthly*, Vol. 96, 1905, p. 483.

[7] Cooley, *op. cit.*, p. 136.

[8] *Op. cit.*, p. 483.

[9] *Op. cit.*, Vol. I., p. 293.

[10] George Otto Trevelyan, "The Life and Letters of Lord Macaulay," Vol. I., pp. 451–454.

within us. No Cæsar or Napoleon has seized "the reins of government with a strong hand."

A wide suffrage is a mental stimulus to the whole community. By abolishing everything that smacks of caste in voting, it arouses in the common man a desire to better his social and economic condition. It promotes an interest in public affairs. It helps the newspapers to keep the public mentally receptive. It fosters a system of education at public expense which begins at the kindergarten and ends with the university. It makes for the amelioration of social conditions. It discourages the growth of an educated aristocracy. It puts the more enlightened under the necessity of persuading the less enlightened to its way of thinking, a work that is no less helpful to the former than to the latter. It helps to widen the circle of readers and stimulates the popularization of knowledge. The market for the numerous books and periodicals that are published to-day depends in part upon universal suffrage. The rule of the people does not necessarily mean government by either the most ignorant or the most enlightened, but it raises the general level of intelligence.[11]

The right to vote has a sobering effect. It arouses a sense of responsibility. It develops self-respect. It makes for patriotism. It gives the foreign-born a sense of oneness with ourselves. It deprives violent men of any valid excuse for violence. It gives zest to freedom of discussion. The right to talk relieves the feelings of the man who talks. The right to vote offers a remedy for all grievances real and imaginary. Neither the reckless utterances of the strike leader nor those of the politician should be taken too literally. The responsibility of office usually sobers the latter, and the former, if placed on the police force, often proves a staunch defender of law and order.

A democratic suffrage is manifestly not suited to every stage of civilization. The wholesale enfranchisement of the negro by the fifteenth amendment was probably a mistake. It is notorious that many of the Latin-American peoples have never achieved anything more than a paper democracy. It is said that Venezuela has averaged one revolution a year during the last thirty years and that one is now six months overdue. Such highly unstable societies exemplify not the rule of the many, but the tyranny of the few. It is as patent, however, that we have progressed beyond the kindergarten stage in democracy as that certain other peoples have not yet reached that stage.

Probably there is no better evidence of this than that supplied by the state of Wisconsin. In freeing themselves from the humiliation of corporate rule, in subjecting the railways of the state to public control, in regulating the public service corporations, in distributing the burden of taxation more equitably, in electoral reform, in articulating the state

[11] Charles W. Eliot, "American Contributions to Civilization," pp. 21–30.

university with the administration of public affairs, and in bringing the services of experts to the aid of the state, the people of Wisconsin have manifested excellent self-control and have conclusively demonstrated their capacity for self-government. The steady growth in popular favor of the state universities of the entire central west is a most reassuring fact. Dependent upon taxation for support and administered by boards elected directly by the people, they have successively raised their standards of admission, greatly increased their enrollments, developed graduate and professional schools, and toned up the secondary schools. In their standards of scholarship, several of them have become the rivals of the older institutions that rest upon private foundations in the east. There has been uncertainty at times, but the open discussion by which these institutions have won their way gives them a most promising future. To what more exacting test could democracy be subjected?

A wide suffrage does not do away with the need of leadership. Only the exceptional man can express the feelings and thoughts of the multitude. Because one man counts as much as another at the ballot box, it does not follow that this is true in the formation of public opinion. There are individuals who contribute in a conspicuous way to the process. The contributions of the masses, while enormous in the aggregate, are small per man.

> One mind in the right, whether on statesmanship, science, morals, or what not, may raise all other minds to its own point of view—because of the general capacity for recognition and deference—just as through our aptitude for sudden rage or fear one mind in the wrong may debase all the rest.[12]

On the other hand, the scrutinizing eye of the multitude lifts the plane of leadership to a higher level. In the words of Ex-President Eliot:

> . . . the collective judgment is informed and guided by the keener wits and stronger wills, and the collective wisdom is higher and surer in guiding public conduct than that of one mind or of several superior minds uninstructed by million-eyed observation and million-tongued debate.[13]

A new type of political leader is coming to the front, one who knows how to address himself directly to the people. The opportunity for the man who does all his work behind the closed doors of a committee room is passing. The call is for men who not only have constructive minds, but who, in addition, have the capacity for leadership and effective utterance on the stump. We are consequently witnessing a revival of public speaking. Never before have good health and a good presence been so indispensable in public life. The change that is taking place is not wholly for the better. As a result, a certain kind of quiet, unobtrusive man may be lost to the public service. Tenure of office for a

[12] Cooley, *op. cit.*, pp. 124–125.
[13] *Op. cit.*, p. 77.

time at least may be more unstable. But the prospect is that what is gained will more than compensate for what is lost. The new type of leader promises to be more stimulating, more informing, more given to discussing questions of justice, and beyond doubt more responsive to the progressive thought of the time. The man who calls other public men to account by reading their votes on the questions of the day is a valuable addition to the public service.

Popular rule may not always command the services of the most efficient men. It may content itself with mediocrity. It may even on occasion elect a crook to office, but, if so, it will not be because he is a crook. Moreover, the crook who owes his position to the people may not act like a crook at all. The people will condone many an error of judgment so long as they believe in a man's honesty. In judging our public men, it is only fair that due allowance should be made for the stinging criticism to which they are exposed. Their motives are all the time called in question, every mistake or weakness is duly noted. If men in the private walks of life were subjected to the same ordeal, many of them would not shine by comparison. Our railway and trust magnates do not always successfully withstand the searching light of criticism.

Some writers who question the wisdom of the referendum admit that the masses are shrewd judges of men. The men elected to public office correspond roughly to what the positions require. Our county and municipal offices are usually filled by rather ordinary men. The governors of the several states represent a better grade of ability. The presidency commands men of a very high order. When it comes to filling important positions, the voters usually display a good deal of sense. As our cities have grown in size and the problem of governing them has become more difficult, more capable men have been elected to municipal offices. This explains the spread of commission government. The general adoption of the short ballot would do away with the needless number of elective offices, concentrate responsibility and help to keep not only the crook, but the mediocre man out of public office. There is no weapon so deadly to dishonesty or incompetency in either public or private life as the certainty of exposure.

The fact that the people do not more frequently prefer college-bred men as their political leaders sometimes occasions regret. But the fact is not necessarily the fault of democracy. It is largely due to the newness of our environment. Life on the frontier encourages contempt for experience, lack of respect for training, a profound faith in natural qualities, and an inordinate respect for the opinions of "self-made men." It rarely suggests the need of the college-trained mind. The failure of college-trained men to gain political recognition is also due occasionally to lack of force and an assumed superiority. The man of books is often disqualified for a life of action. The gradual extension of the merit

system and the growing number of experts employed in the conduct of governmental affairs indicate that democracy is not necessarily inconsistent with efficiency in the public service. In any event, an influential portion of the property-owning class is no less responsible than the working class for the manifest failures in our municipal, county, state and federal governments. The mistake of supposing that some new kind of political machinery, such as commission government, will work desirable results without the watchful eye of an intelligent electorate is not confined to any one class.

It does not follow that the services of a man who is not elevated to an elective office are lost to the country. The case of Mr. Bryan, whom an error of judgment on the silver question and the "cross of gold" speech brought into prominence, is a good illustration. He has never reached the presidency, but as the critic of his own as well as of other parties he has rendered the country more distinguished service than some who have reached the highest office in the gift of the people. Many of the positions of greatest influence are outside of public office. There is no occasion to despair of the influence of the educated man who can think and express himself clearly.

> We may rail at "mere talk" as much as we please, but the probability is that the affairs of nations and of men will be more and more regulated by talk. . . . there can be no doubt that it is talk—somebody's, anybody's, everybody's talk . . . by which each generation comes to feel and think differently from its predecessor. No one ever talks freely about anything without contributing something, let it be ever so little, to the unseen forces which carry the race on to its final destiny. Even if he does not make a positive impression, he counteracts or modifies some other impression, or sets in some train of ideas in some one else, which helps to change the face of the world.[14]

The late Edwin L. Godkin justly complained of the influence of the boss in our nominating system, of the decline of our state legislatures, of the prevalence of the spoils system, of the lack of public spirit, and of our failures in municipal government.[15] These evils are still with us, but the changes that have taken place, while leaving much to be desired, have been, for the most part, in the right direction. In no respect has there been greater improvement than in the weakening of party ties and the growing influence of the independent voter. An excessive loyalty to party was one of the unfortunate results of the Civil War. In the South, voting the democratic ticket became almost a *sine qua non* for admission to polite society. In many northern communities, the republican party

> was merely a synonym for patriotism, another name for the nation. One became, in Urbana and in Ohio for many years, a Republican just as the Eskimo dons

[14] Edwin L. Godkin, "Problems in Modern Democracy," pp. 221, 223 and 224.

[15] See "Unforeseen Tendencies of Democracy," *passim.*

fur clothes. It was inconceivable that any self-respecting person should be a Democrat. There were, perhaps, Democrats in Lighttown; but then there were rebels in Alabama, and in the Kuklux Klan, about which we read in the evening, in the Cincinnati *Gazette*.[16]

Party loyalty within reason serves a useful purpose. It gives stability to public policy. It holds the party together for future contests. It may mean devotion to principle, if the party stands for some great cause. None-the-less, a blind devotion to party has been the bane of our politics. It has introduced the extraneous issues of national politics into our state and municipal contests. It has kept the unprincipled leader in power. It has countenanced alliances between political machines subservient to the same sinister influences. It has acted as the catspaw of the interests which participate in politics for private gain, the most consistent of non-partisans. The growing independence of the electorate is consequently a hopeful symptom. The greenback and populist movements helped to break the crust of habit in voting, whatever one may think of some of the vagaries for which they stood. The gold democrats in 1896 helped to save the country from free silver, and the independent democrats in New York City, Baltimore and Maryland have repeatedly saved the cause of good government by breaking with their party. The independent republicans in Cincinnati, Cleveland and Philadelphia have done a similar work. The independents in all parties in Toledo and Chicago have greatly improved the tone of municipal government. The results of the referenda in Ohio, Oregon and other states show a disposition on the part of the voters to discriminate. Party organizations give coherency to political action, but the influence of the independent voter is necessary to keep them within bounds.

The increase of the Socialist vote is exerting a wholesome influence, however much one may dissent from some of the cardinal points for which the party stands. It forces people to reexamine the foundations of their political faiths. It obliges the leaders of other parties to revise their platforms. It gives large numbers for the first time in their lives a political cause worthy of their devotion. Some news-dealers like to sell *The New York Call* for the sake of the cause which it represents. Many corner and bar-room loafers, now that they have become Socialists, are no longer purchasable on election day. A man who handled large sums of Senator Stevenson's money in Wisconsin testified that no money was used in the strong Socialist wards of Milwaukee.

The moral is clear. The remedy for our political ills lies in quickening the general intelligence and in appealing to the idealism latent in the people rather than in a narrow suffrage. The latter will not save

[16] Brand Whitlock, "Forty Years Of It," *The American Magazine*, January, 1913, p. 18.

us from the danger of corruption. A century or more ago, the suffrage was anything but democratic and yet there was scarcely any kind of political chicanery which the men then in public life did not practise. "In filibustering and gerrymandering," writes Professor McMaster, "in stealing governorships and legislatures, in using force at the polls, in colonizing and in distributing patronage to whom patronage is due, in all the frauds and tricks that go to make up the worst form of practical politics, the men who founded our State and national governments were always our equals, and often our masters."

While no one can be blind to the evils which have been associated with democracy in the United States and in the Old World, no serious student of history, when he compares the long train of abuses, brutalities and disorders connected with the rule of kings, priests and nobles, can doubt for an instant that as between democracy and the outworn systems of the past there can be no choice. Every branch of law that has been recast under the influence of popular will has been touched with enlightenment and humanity. Compare the brutal criminal codes of old Europe with the still imperfect but relatively enlightened codes of our own time. Compare the treatment of prisoners, women and children, the education of the youth, and the public institutions devoted to general welfare, with those existing before the age of democracy. Mr. Bryce's remark that evidences of philanthropy and humanitarianism are mingled in our state politics with folly and jobbery "like threads of gold and silver woven across a warp of dirty sacking" is true, and yet when one looks for evidences of philanthropy and humanitarianism in the folly and jobbery that characterized aristocratic and monarchical institutions in the old régime, one does not even have the satisfaction of getting the gleam of gold and silver across the dirty sacking.[17]

[17] Charles A. Beard and Birl E. Schultz, *op. cit.*, p. 14.

(*To be concluded*)

THE FUTURE OF THE CHESTNUT TREE IN NORTH AMERICA

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NOW-A-DAYS one often hears the question, "What is going to become of our chestnut trees?" In fact, whenever the subject of trees is broached in the course of a conversation, this inquiry is bound to come out—not, as I believe, that the interrogator hopes to receive a satisfactory answer, but more in the way of a general query.

As I do not claim to be gifted with second sight, I do not mean to imply by the title of this paper that I can foretell the future of this tree—rather, in the same philosophical spirit of the interrogator, on the basis of certain facts relating to the past and present history of the species, I shall make an inquiry into its probable future.

It is natural that the condition of this tree should arouse concern, valuable as it is to us in a great variety of ways. For one thing, we are always in need of woods which, like the chestnut, are comparatively resistant to decay when in contact with the soil; and this is one of the main reasons why a large proportion of the railroad ties and telegraph poles in the eastern United States are of chestnut. However, as far as the finer, technical uses are concerned, such as interior finish of houses, furniture, etc., it is a decidedly second-class material because of its warping and checking tendencies; yet it is often used for these purposes, where the element of cheapness is the chief consideration. By the uninitiated, chestnut used in interior house finish may easily be mistaken for the more expensive ash. One of the chief sources of tannic acid, important in leather manufacture, is our chestnut tree. And every small boy, not to mention his elders, knows the value of the nuts, which are sweeter than those of its near relative, the European chestnut.

In addition to these valuable properties, when it grows in the open, the tree develops a massive, round head, with short, powerful trunk, and low-sweeping limbs, which make it a most beautiful ornamental tree (Fig. 2).

The natural range of the chestnut (*Castanea dentata*), is from southern Maine[1] to the valley of the Winooski River in northern Vermont, to southern Ontario, and along the shores of Lake Ontario[2] to southeastern

[1] Knight, Ora W., "Some Noteworthy Plants of the Penobscot Valley," *Rhodora*, 8: 65–66, 1906.

[2] Sargent, C. S., "Silva of North America," 9: 14, 1896.

Michigan,[3] southward in the eastern part of its range to Delaware, and in the west to southeastern Indiana[2] and extreme southern Illinois,[4] while it extends along the southern Appalachians to north central Georgia,[5] central Alabama[6] and Mississippi, and central Tennessee. This distribution is most easily remembered if we observe that it takes the general form of an ellipse, which is about twice as long as broad, with the southern end in central Mississippi, Alabama and Georgia, the northern end in Maine, New Hampshire and Vermont, while the greatest cross diameter of the ellipse extends from southeastern Michigan to Delaware (Fig. 1).

Although this is the area which now includes all chestnut growing naturally or "wild" in the United States, it does not necessarily represent the territory it has always occupied in the past. For geological evidence, as well as our own observational powers, show us that in both plant and animal worlds the confines of a species are constantly varying —now expanding, now contracting. This condition is evidently due to a great variety of factors, but at the very groundwork of them all lie the fundamental principles of the struggle for existence and the survival of the fittest. In modern times the modifying action of man on this perpetual contraction or expansion of a species has been by no means slight, and with the ever-increasing facilities of commerce, his influence is becoming more and more marked. To cite an example from the plant world, some of the most obnoxious weeds that grow about us to-day, and are the bane of the farmer, are intruders from foreign countries, their seeds having been brought in with various imported materials. Having thus arrived here, many of them find congenial soil and make their home among us, thereby considerably widening the range of distribution of their particular species. On the other hand, by the unwitting introduction of various fungous or insect parasites, man may be instrumental in the contraction or even the extinction of some of our plant or animal species.

Such examples as the bison, or the North American Indian, demonstrate how rapidly the distribution of a species or race may change, even within the memory of man.

Geological data, as furnished us in the form of fossils, are often illuminating as to the former distribution of our plant and animal species. For example, the giant big-tree and redwood, of California, quite prob-

[3] Otis, C. H., and Burns, G. P., "Michigan Trees, a Handbook of the Native and Most Important Introduced Species," p. 95, Ann Arbor, 1913.

[4] Gleason, H. A., "Additional Notes on Southern Illinois Plants," *Torreya*, 4: 168, 1904.

[5] Harper, R. M., "Flora of Middle Georgia," *Bull. Torrey Bot. Club*, 27: 333, 1900. "Botanical Explorations in Georgia During the Summer of 1901," *ibid.*, 30: 294: 1903.

[6] Mohr, Charles, "Plant Life of Alabama," Contributions from the U. S. Nat. Herbarium, 6: 60, 1901.

ably had formerly a much wider range than their present contracted limits, for fossils of conifers belonging to the same genus have been found even as far north as Greenland. And it is reasonable to assume that, if conditions remain the same, such species will continue to weaken and die out, although in this case also man's treatment can considerably modify the result.

Unfortunately, in the case of the American chestnut, there is no fossil evidence of its former distribution. Mr. F. H. Knowlton, of the United States Geological Survey, writes us: "So far as I know, the American chestnut has not been found fossil anywhere in this country, but the parent form, that of *Castanea sativa* (the European chestnut)

FIG. 1. SHOWING THE NATURAL RANGE OF THE AMERICAN CHESTNUT. The cross hatching shows in a general way the extent of territory covered by the chestnut bark disease.

has been found at a number of localities in England and Italy, in deposits of inter-glacial or pleistocene age." As far as the genus is concerned, *Castanea* once had a much wider range in North America than at present, for, according to Sargent,[7] "Before the middle tertiary period *Castanea* existed in northern Greenland, and in Alaska, where traces of the leaves and fruit of *Castanea Ungeri* Heer have been distinguished;

[7] Sargent, C. S., *loc. cit.*, p. 10.

and impressions of one and perhaps two species found in the miocene rocks of Oregon, and in those of the upper miocene of the Colorado parks, show that *Castanea,* which already existed in Europe in the cretaceous period, once inhabited western North America, whence it has now disappeared."

Coming now to the condition of the chestnut tree to-day, let us first figure up its liabilities, *i. e.,* those diseases and injuries from which it is prone to suffer, and then set down on the other side of the balance sheet its assets, *i. e.,* those inherent qualities which accrue to its advantage in the struggle for existence.

It is a significant fact that both the European and the American chestnuts have been attacked in recent years by serious diseases which have attracted a great deal of attention here and abroad. In Europe the disease known as the *Male dell' Inchiostro* and various other troubles have very seriously affected the European chestnut.

In the United States, the well-known bark disease, discovered in 1904 near New York City, has already caused enormous damage to the chestnuts in southern New England, New York, New Jersey, Pennsylvania, Delaware and Maryland, and it also occurs in Virginia and West Virginia[8] (Fig. 1). It is unnecessary here to describe this trouble in detail, as excellent accounts of it have already been published and are easily available.[9] It is sufficient to state that it is caused by a fungus which grows in the living bark of the tree, gaining an entrance through wounds or openings of any sort in the bark. As the fungus grows, it kills the bark, and by gradually increasing the radius of its operations, eventually reaches around the trunk or branch which it entered, in this way girdling it.

When this disease was first discovered, and its disastrous nature realized, one of the first questions that arose was that of the source of the causal fungus. Where did this fungus come from? Was it a native fungus, or was it brought into this country from abroad? It was easily seen that the answer to this question was of fundamental importance, for if the fungus was a native species, then its sudden attack was evidently due to unusual environmental factors of some sort, and with the recurrence of the normal conditions the virulence of the attack would cease. On the other hand, if the fungus were an imported parasite, there would be no telling where its depredations would end.

Those who held to the first theory, *i. e.,* that the fungus was a native

[8] The disease has also been recently reported in a nursery in North Carolina. See Metcalf, Haven, "The Chestnut Bark Disease," *Jour. of Heredity,* 5: 8–18, 1914.

[9] Metcalf, Haven and Collins, J. Franklin, "The Control of the Chestnut Bark Disease," U. S. Dept. of Agr., Farmer's Bull., 467: 1–24, 1911.

Clinton, G. P., "Chestnut Bark Disease," Rept. of Conn. Agr. Expt. Sta., 1912, 359–453; pls. 21–28, 1913.

form, believed that it had hitherto escaped the notice of botanists, occurring in an inconspicuous way as a weak parasite or saprophyte, but that conditions unfavorable to the chestnut, such as extremely cold winters and severe droughts, continued coppicing, etc., had rendered the tree susceptible to attack. As to the suddenness of the outbreak, this was to be accounted for by the very unusual climatic conditions which prevailed about the time of its appearance. Moreover, serious troubles of the chestnut had been before noted in this country, but had never been really explained.

On the other hand, those who believed the fungus to be an introduced species pointed to its apparent spread from the region around New York City as a center, our greatest port of entry, to the suddenness of the attack, to the fact that the fungus had never been observed here before, and lastly, to the partial immunity of certain varieties of the Japanese chestnut, which were first raised extensively on Long Island, the implication here being that the fungus might be a Japanese species to which, in their native home, the Japanese chestnuts had in the course of a long period of time become partially immune.

The last point was significant, but not conclusive, since the fungus had never been found in Japan, nor was it possible at the time to locate it in any foreign country.

In the course of time investigations brought out the fact that the fungus was closely related to a species already known in Europe and America, and by some was considered a variety of this, while others regarded it as a distinct species. Without going into details, it is sufficient to note the main fact emerging from them, namely, that the fungus was a new form, at least one not before known in Europe or America.

For a long time efforts to locate the fungus in the orient were without avail, but recently Mr. Frank N. Meyer, of the United States Department of Agriculture, has sent to Washington specimens from a blighted chestnut in China, which have been found to contain the identical fungus which has caused the trouble here. Moreover, from the nature of the locality in which it was collected, the fungus appeared to be indigenous. It should also be noted that the Chinese trees gave the appearance of being much more resistant to the disease than the American.[10]

Unless, indeed, we construct a theory of independent origin of species identically the same, due to essentially similar conditions of environment, we are justified, then, in believing that this parasite was brought into this country, and, judging from the past, may continue its steady

[10] Shear, C. L., and Stevens, N. E., "The Chestnut Blight Parasite (*Endothia parasitica*) from China," *Science*, N. S., 38: 295–297, 1913.

Metcalf, Haven, "The Chestnut Bark Disease," *Jour. of Heredity*, 5: 8, 1914.

advance in the area in which the chestnut naturally occurs. However, we shall consider this point again later.

In common with other forest trees, the chestnut is subject to the attack of several species of fungi which bring about a decay of the heart wood. Normally, the tree is protected from such invaders by its incasement of bark, but when this is injured in any way, a vulnerable spot is opened up through which fungi can enter. Notably is this the case in trees injured by forest fires, for here the living bark as well as the sapwood underneath may be entirely killed in spots, causing the so-called fire-scars, and furnishing an easy ingress for fungi. Once inside, in the heartwood, the fungus may work up and down in the interior of the trunk, softening the wood by its decaying action, or "dozing" it, as the lumbermen say. If the tree, thus deprived of the firmness of its solid cylinder of heartwood, its chief mechanical support, does not fall a prey to the next violent windstorm, it is in any case weakened, and the way lies open for attack upon its last stronghold, the sapwood and living bark.

Another widespread trouble of the chestnut, which I have found of common occurrence in New England forests, but apparently more destructive in the southern Appalachian mountains, is caused by the attack of the two-lined chestnut borer, *Agrilus bilineatus*. Next to the fungus which causes the bark disease, this insect is perhaps its most serious enemy. It is said to have a preference for trees enfeebled in some way, through such causes as drought, unfavorable soil conditions, etc., yet it is possible that where it breeds in great numbers it may be forced to attack vigorous individuals. In any case I have seen many examples of trees, which to all appearances had been in a perfectly sound condition, being rapidly killed by the attacks of this tiny grub. On opening up the inner bark, the long, sinuous channels of the larvæ were disclosed, now and then with a sharp turn in a lateral direction, the combined effects of several of these galleries resulting in a practical girdling of the tree. Many other insects attack the chestnut, but they are of secondary importance.

Let us next consider the practise of "coppicing." As is the case with many other of our forest trees, the chestnut habitually sends up sprouts from the stumps of felled trees, sometimes more than one hundred of these developing from a single parent stump. These "coppice" shoots grow rapidly, having the well-developed roots of the parent tree at their disposal for the absorption of nourishment from the soil, and enter into fierce competition with one another for light and space. Although in the natural course of events the weaker ones succumb and die out in the struggle, the woodsman may assist nature in this process of elimination by cutting out the weaker shoots early, in order to give the more vigorous ones a better chance In either case, eventually four or five, or rarely

more, vigorous trunks remain, which on reaching a suitable size are cut down and used for railroad ties, telegraph poles, or lumber, as desired; and from their stumps new coppice shoots arise, to repeat the whole history of their forebears. In some regions this coppicing has gone on for four or five generations of sprouts.

The question now before us is, "Does this continued coppicing weaken the vitality of the chestnut tree and thus make it more susceptible to disease?" The general opinion seems to be in the affirmative. Zon,[11] speaking of the chestnut in southern Maryland says:

> It must not be forgotten, however, that a chestnut stump can not go on coppicing forever. With each new generation of sprouts, the stump becomes more and more weakened, and hence gradually loses its capacity to produce healthy and vigorous sprouts. Although it is impossible to state with certainty how many generations of chestnut can be raised from the same stock without impairing the vitality of the sprouts, the effects of repeated and bad coppicing manifest themselves in the increasing number of dying chestnuts all over Maryland. The immediate cause of their death can nearly always be traced to attacks of either insects or fungi, yet the prime reason is their decreased vitality, which makes them easy prey to their natural enemies.

As stated by Dr. Clinton:[12]

> It is certainly a curious coincidence that the blight makes its first appearance and causes its greatest damage in the regions where the chestnut has suffered most from repeated cutting over.

Dr. Clinton quotes Nellis, of the U. S. Forest Service, who, in an unpublished working plan on "Utilization of Blight-killed Chestnut," writes:

> It is expected that this study will show that the present range of the chestnut bark disease is in a region of entirely second growth chestnut, which has been culled of its most valuable timber, where only rough products are now being produced.

Without entering into the discussion as to the relation of the bark disease to coppiced areas, I will merely state that coppiced chestnut is in general apt to be affected with disease of some sort. Especially frequent are heart-rotting fungi which may enter by way of the decaying parent stump, and the unsound condition of the trunk they cause is communicated to succeeding generations. It is also conceivable that the root system of the sprouts, inasmuch as it is partly that of the parent tree, may be weaker on this account. For, although we have no evidence to prove that the parent root system becomes inherently weaker with age, yet it is reasonable to expect that the soil about it would become more and more exhausted of its nourishment, to say nothing of possible external injuries to which it might be subjected in the course of a long period of time.

As already intimated, forest fires are extremely disastrous to the

[11] Zon, R., "Chestnut in Southern Maryland," Bureau of Forestry, U. S. Dept. of Agric. Bull., 53: 29, 1904.

[12] Clinton, G. P., *loc. cit.*, p. 402.

chestnut, not only by reason of their direct effect where they kill the tree outright, but also by exposing its interior to the attacks of fungi and insects. In addition, such fires impoverish the soil by burning out the humus, thus materially lessening its fertility. Reproduction also receives a setback because seedlings, young sprouts, or nuts lying on the ground ready for germination, are easily killed. Forest fires have been abundant throughout the range of the chestnut tree, and it is reasonably certain that they have been much more frequent since the white man has settled these parts of North America. In the southern Appalachians, the deadly work of fire, followed by insects and fungi, is to be seen on every hand. In this connection the following citations give us some conception of the general condition of the chestnut in the southern Appalachians.

Dr. Mohr,[13] speaking of the chestnut in Alabama, says:

> The chestnut, usually one of the most frequent trees of these forests, is at present rarely found in perfection. The older trees mostly show signs of decay, and the seedlings, as well as the coppice growth proceeding from the stumps, are more or less stunted. It is asserted by the old settlers that this tree is dying out all over the mountainous regions, where at the beginning of the second half of the century it was still abundant and in perfection.

W. W. Ashe,[14] says:

> For many years the chestnut on the lower mountains in the southeastern portion of the state has been dying out, a few trees at a time. . . . Some of these are killed by the two-lined chestnut borer, but while this decline is in part due to the ravages of the borer, it seems to be due more to excessive burning and to the consequent destruction of humus and impoverishment of the soil.

W. P. Corsa,[15] states:

> From causes not well understood, there is a marked decline in the vigor of the chestnut throughout the broad area of territory in the southern states where the white man found this tree among the most thrifty of the original forests. Down to the first quarter of the present century there seems to have been no mention of a trouble in the chestnuts of that section. Within the memory of residents of the Gulf States the chestnut flourished in all their higher lands. In point of time the trouble seems to have begun in the most southern limit of chestnut growth, and there the destruction has been most complete. It has pushed its encroachments throughout Mississippi, Alabama, Georgia and South Carolina, and is now reported in the strongholds of chestnut growth in North Carolina, Tennessee and Virginia.

Buttrick,[16] in a study of the conditions in North Carolina, says:

[13] Mohr, Charles, *loc. cit.*, p. 61.

[14] Ashe, W. W., "Chestnut in Tennessee," State Geol. Survey of Tennessee, published in cooperation with the Forest Service, U. S. Dept. of Agr. Bull., 10-B, p. 11, 1912.

[15] Corsa, W. P., "Nut Culture in the United States," Unnumbered Bull. of Div. of Pomology, U. S. Dept. of Agric., 1896, p. 78.

[16] Quoted by permission, from the manuscript of a report on the chestnut in North Carolina, prepared by P. L. Buttrick, under the joint direction of the

FIG. 2. AMERICAN CHESTNUT, CENTRAL MARYLAND. Photograph supplied by the United States Forest Service.

It is well known that chestnut was much more abundant and important throughout the Piedmont region and at places in the mountains themselves than is the case to-day.

Records show that during the first half of the past century, chestnut formed an important part of the growth forest throughout the western Piedmont section, although probably never as important a one as in the mountains. It was also apparently found much farther east than at present and may have at one time reached the Coastal Plain.

About seventy-five years ago it began to die throughout the eastern portion of the plateau and by the sixties it was dying throughout Guilford county and to the west. In the early eighties it began to die throughout Iredell, and the counties north and south of there. Since then the "death wave," as we may call it, has traveled west and overflowed the Brushy and South Mountains; has reached half way up the slopes of the Blue Ridge, and is still rising in the

Laboratory of Forest Pathology, U. S. Dept. of Agric., and the North Carolina Geological and Economic Survey; and soon to be published by the latter.

northern and has actually crossed it in its southern section. West of the ridge in most of the regions where chestnut is wanting, its disappearance has been quite recent and, indeed, it is still disappearing.

This strange phenomenon is not confined to North Carolina, but is to be seen to a greater or less extent on the outer portions of the range of the chestnut, throughout the southern half of its range. Reports show that chestnut has largely died out or was formerly much more abundant in portions of Virginia, South Carolina, Georgia, Alabama, Mississippi and Tennessee, and that the recession is still going on.

This apparently mysterious decline in vigor of the chestnut in the south is evidently not due to any one factor, but probably to a variety of causes. Probably frequent forest fires are to blame for the beginning of most of the trouble, and these, as we have seen, are followed by the attacks of fungi and insects. The cutting over and clearing up of large areas may also result in soil conditions which are not as favorable as formerly. Climatic changes may also have something to do with the case.

If we summarize briefly the troubles of the chestnut described in the preceding pages, we find that in the northern half of its range it is a prey to the bark disease; throughout its whole area it is attacked by the two-lined chestnut borer, as well as by other insects, and also by fungi which destroy the heartwood. The common practise of coppicing can only be regarded as harmful when carried on for several generations. Forest fires have been frequent, resulting in injuries of many sorts. In the southern states still other factors are evidently at work.

Let us now turn to the other side of the balance sheet, *i. e.*, to the assets of the chestnut, those traits in its life and habits which are of advantage to it in the struggle for existence and the perpetuation of the species.

Of first importance is its rapid and vigorous growth. Among the numerous advantages to be derived from this is the power to close over any chance wounds with new tissue with greater ease than would be the case in a more slowly growing species. And we have already seen how wounds may open the door to disease and decay.

An inherent power for rapid growth also enables the tree to develop roots quickly in times of need, and also, in competition with other species in the forest, to lift its crown above them in order to secure better light. Moreover, in this connection we should recall that the chestnut is fairly "tolerant," *i. e.*, not easily killed out or injured by the shade of older, larger trees.

As regards its soil requirements, we find that, unlike such trees as the tulip or basswood, it is not at all fastidious. Its principal needs seem to be an adequate amount of moisture in the soil, for it appears to be quite sensitive to drought, and also a soil which is fairly deep and loose. As to the chemical nature of the soil it is not particular, except that it rarely grows in a limestone region. Neither need the soil be a fertile one, for chestnut trees grow and thrive on sterile soils, provided they be porous

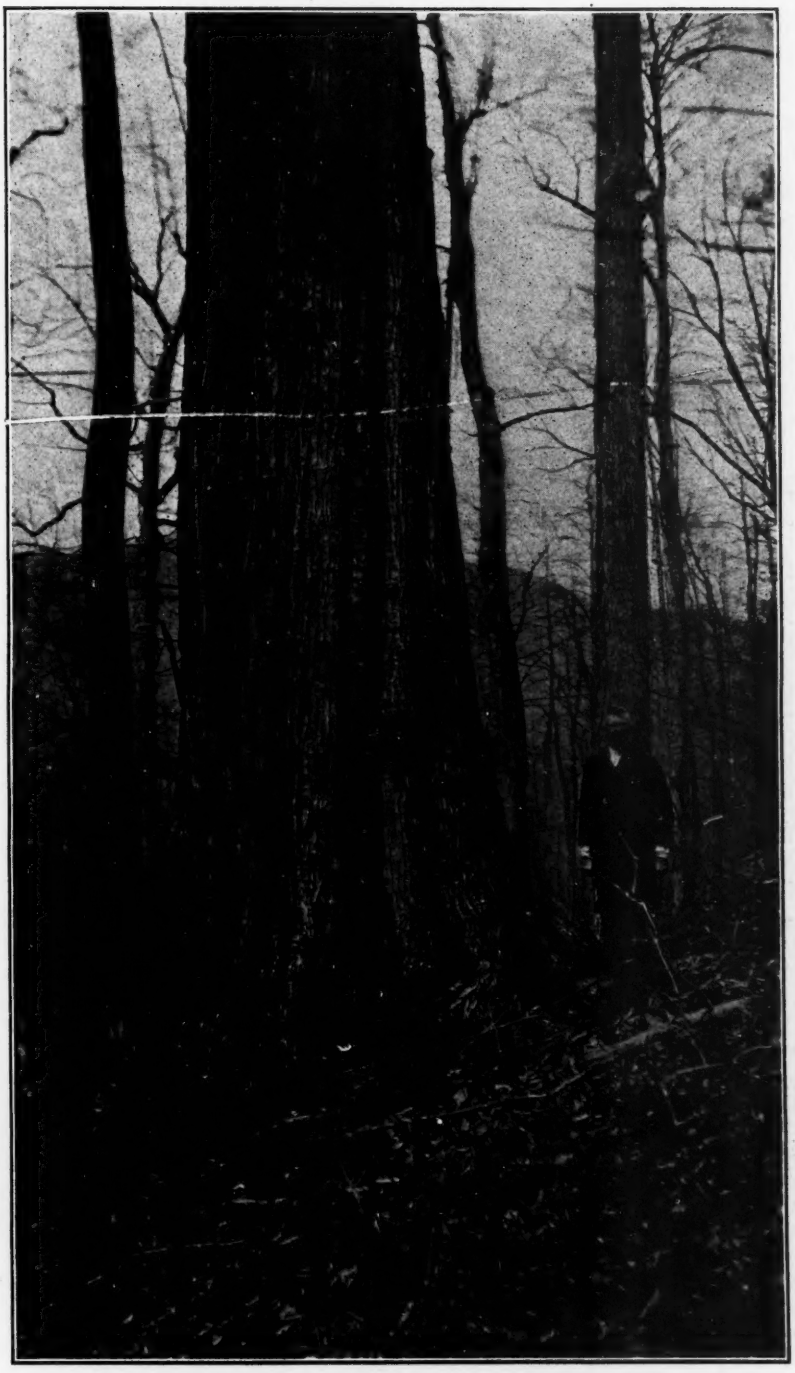


FIG. 3. AMERICAN CHESTNUT, MITCHELL COUNTY, NORTH CAROLINA. Photograph supplied by the United States Forest Service.

and have a sufficient underground supply of moisture. In the matter of soil requirements, therefore, it is easily suited, and it is hardly necessary to add that this is a distinct asset on the side of the perpetuation of the species.

Just as is the case with other organisms in both plant and animal kingdoms, all our tree species possess an average age limit. Some of the individuals of the species live longer, and others die out before the limit is attained, but to every species one might assign an average length of life. This age limit differs, of course, with different species: for example, some of the oaks are notably longer lived than such species as the aspen or the gray birch. Some of the causes of these differences in longevity are obscure, and this is not the place for their discussion. What we wish to point out is that trees as well as animals, vary in their age limits.

Now, a tree, on reaching maturity, begins to reproduce, that is it forms seeds, which, if they find conditions suitable for them, develop into individuals like their parent. I have here in my yard a silver maple, the seed of which I planted in 1904. Two years ago, in 1912, when it was eight years old, and about ten feet high, it bore a few blossoms and seeds. Last year more seeds were produced than the year before, and this year it is loaded with blossoms. Although still a small tree, not yet ten years old, it is arriving at maturity, and is able to reproduce itself. It should continue to do this until the end of its life. Of course under modern city conditions, where, among other disturbing elements, the ubiquitous lawn mower can always be counted on to do its deadly work, it is a question how many, if any, of its descendants will survive. But, nevertheless, here or anywhere, the *chances* of reproducing its kind depend ultimately on the number of seeds it bears, and this number, again, depends directly on the length of its life.

It is clear then that with two species with differing age limits, other things being equal, the species which is longer lived would have the better chance to perpetuate its kind.

When we consider the genus *Castanea,* we find it especially favored in this respect, for it has long been noted for its longevity. The following extract from Sargent's[17] "Silva of North America" is of interest in this connection:

> The Tortworth chestnut tree on the estate of the Earl of Ducie, in Gloucestershire, which is still in a healthy condition, was remarkable for its great size in the reign of Stephen, who ascended the English throne in 1135, and is probably considerably more than a thousand years old. In 1776, the short trunk of this remarkable tree measured fifty feet in circumference at five feet from the ground.

Further on, writing of trees on Mt. Ætna, in Sicily, Sargent says:

[17] Sargent, C. S., *loc. cit.,* 9: 8, 1896.

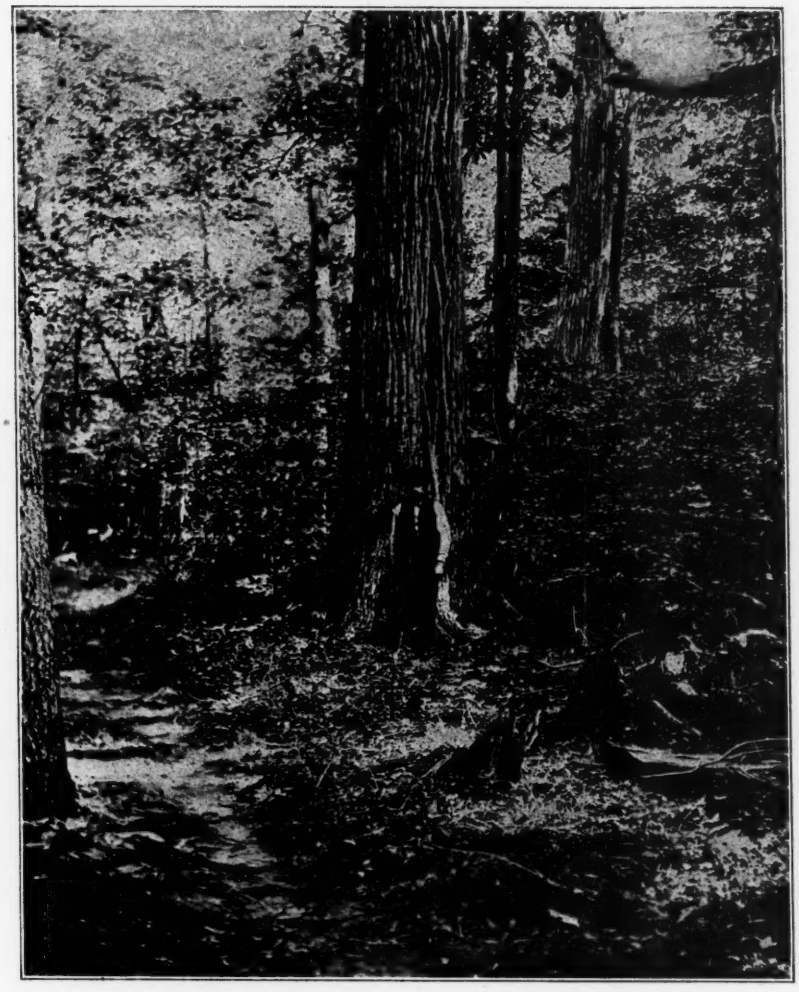


FIG. 4. CHESTNUT TREE, NEAR THE TRAIL TO BUCK SPRING LODGE, PISGAH FOREST, NORTH CAROLINA. This tree measured eighteen feet in circumference. Photograph supplied by the United States Forest Service.

The trunks of two of these Sicilian trees measured sixty-four and seventy feet in circumference: and at the end of the last century the low trunk of . . . the largest of the trees had a circumference of nearly two hundred feet at the surface of the ground. . . . Trees with trunks from twenty to thirty feet in circumference and believed to be at least a thousand years old, are not uncommon in southern Europe, where the chestnut is the largest, and with the exception perhaps of the olive, the longest lived inhabitant of the forest.

The above quotations apply of course to the European chestnut. In North America large trees of the native species are also not rare (Figs. 3 and 4). Although definite data as to their ages are wanting, they show enough for our purpose, namely, that the American chestnut shares in the family characteristic of extreme longevity enjoyed by its European relative.

I have already spoken of the sprouting capacity of the chestnut, and for various reasons have stated that when coppicing is too long continued it can only result harmfully. On the other hand, the sprout-producing ability *per se* should be reckoned as a distinct advantage to the species. We know that when the lumberman fells such trees as the pine or hemlock he sounds the death knell of that individual. On the contrary, in the case of the chestnut, as we have seen, this is just the operation which leads the way to an increase in the number of individuals, for where one tree existed before, now four or five ultimately develop, sprouting from the stump. This kind of "vegetative" reproduction which, eventually, of course, results in increased seed production, is naturally an important factor in prolonging the life of the species. Zon[18] says of the chestnut in southern Maryland:

> Were it not for its sprouting capacity and its frequent occurrences on slopes difficult to till, chestnut in Maryland would be a species of the past, as white oak and several other species are fast becoming.

There is, possibly, another point which may be in favor of the chestnut tree, although it applies only to the southern representatives of the species. As far as we can judge from reports and surveys, the progress of the chestnut bark disease into the southern states has been slow: at least, it has apparently spread into this territory with no such rapidity as has been remarked in the northern states.

Under the circumstances, it is entirely reasonable to assume that some condition exists in the south unfavorable to the development of the blight fungus. Various explanations have been offered, but none of them is more than a hypothesis, since, as far as I know, no accurate scientific investigation of the case has been made.

Perhaps the most plausible theory is to the effect that the southern chestnut may contain a larger amount of tannin than the northern tree and that this higher content of tannin may be inimical to a vigorous development of the fungus. Whether it is actually a fact, however, that a southern tree contains more tannin than a northern tree of equal age, has not been determined. We know that the tannic acid manufacturers use only southern chestnut for their material, and yet this may be simply because larger trees exist in the south, and we know that the older, larger trees contain more tannin. The actual comparative tannin content of northern and southern trees would form an interesting subject for future investigation. Dr. Clinton,[19] acting on the supposition that some such relation as this might exist, has carried on some interesting experiments with the chestnut blight fungus in culture media containing various percentages of tannic acid. He has found, among other

[18] Zon, *loc. cit.*, p. 13.

[19] Clinton, G. P., *loc. cit.*, pp. 404–407, and pp. 430–434.

things, that while the fungus grew vigorously up to a certain percentage of tannic acid, its development was very sensibly retarded if the percentage was slightly increased beyond this point. If the southern tree actually contains a large amount of tannin we should have here a fundamental barrier to the advance of the chestnut blight fungus, and thus a decided advantage in favor of the southern representatives of the species. However, as I have already intimated, the whole matter is theoretical, since there is entirely insufficient evidence to substantiate it.

If we summarize, then, the points which the American chestnut has to its credit on the asset side of the balance sheet, we find that it exhibits a rapid and vigorous growth, it is fairly tolerant, at least in youth, it is not over particular as regards soil requirements, it enjoys longevity as an inherent characteristic, it reproduces itself by sprouting from the stump, and finally, as regards the trees in the southern section of its range, their supposedly larger content of tannin may prove to be a protective power against the annihilating advances of the bark disease.

This list is impressive—in fact, one could hardly conceive how the species could be more favored, and, indeed, these are undoubtedly the main reasons why it has been so firmly established and abundant throughout its range.

When we review the troubles by which it is assailed on every hand, it is remarkable how many of them are due primarily to man's activities: as, for example, the introduction of the bark disease, continued forest fires, repeated coppicing, change of soil conditions from cutting over large areas, etc. And although through the efforts of a few some of the evils may be checked or diminished, from the complex nature of the case, the deadly work will inevitably continue. One can not avoid the conviction, therefore, that, if the present conditions persist, the virtual extinction of the American chestnut is only a question of time. In the south it is dying out where it once flourished, and in the north its general condition is such that it may soon cease to be classed as an important timber tree. How long it will survive it is of course impossible to predict with any degree of exactness. But at the present rate of decline its future life may possibly be measured in hundreds of years, but not in thousands.

The most hopeful indications for chestnut in North America in the future lie along the line of breeding experiments. Since the blight is our worst enemy, work on the development of varieties immune to this is of the highest value. It has long been known that certain Japanese forms are somewhat resistant to the blight, and the disease is comparatively inconspicuous on the Chinese chestnut, on which it has recently been found.[20] Fortunately work on hybridization of chestnut species had been started long before the blight was discovered in this country. Among

[20] Metcalf, Haven, *loc. cit.*

the investigators in this field, Van Fleet,[21] of the United States Department of Agriculture, crossed Asiatic and European forms with the American chestnuts, the latter consisting of *Castanea dentata,* the forest tree, and *C. pumila,* a shrubby species growing in the southern states. The last species appears, by-the-way, to be somewhat resistant to the blight. Van Fleet says:

> The results of these undertakings have been successful, in the main. The appearance in 1907 among our plantings of the terribly destructive new bark disease organism, *Endothia parasitica,* put a summary termination to the experiments with *C. americana* (*dentata*) and its derivatives, but selection work has since continued with self and chance-pollinated individuals of the chinquapin and Asiatic types. . . . The Asiatic chestnuts, and the chinquapin-Asiatic hybrids, are plainly highly resistant. Few have shown any appearance of infection and when noticeable the injury is quite local in character. Second generation seedlings of chinquapin-crenata crosses show no disease at all although always exposed to infection.

The nuts produced by these chinquapin-Asiatic hybrids are of decidedly superior quality, so that, if they continue free from disease, they will solve the problem from the standpoint of the chestnut orchardist. It is doubtful, however, whether they will ever attain the size of forest trees. But it is quite possible that an immune variety for timber purposes may be produced by crossing a form like the Chinese chestnut, *C. mollissima,* with our native forest tree.

Work of this kind is extremely valuable and, although slow in yielding results, may eventually prove to be the only means of continuing the existence in our land of a greatly esteemed tree.

[21] Van Fleet, Walter, "Chestnut Breeding Experience," *Jour. of Heredity,* 5: 19–25, 1914.

CLAUDE BERNARD

By D. WRIGHT WILSON

ONE hundred years ago, in a little village in eastern France, there was born of humble parentage a man who was to become one of the greatest physiologists of France and of the world. Though a pioneer in a field despised and looked down upon at the time, he was to make discoveries which were of fundamental importance to physiology and medicine and were to influence the whole general aspect of biology toward certain questions.

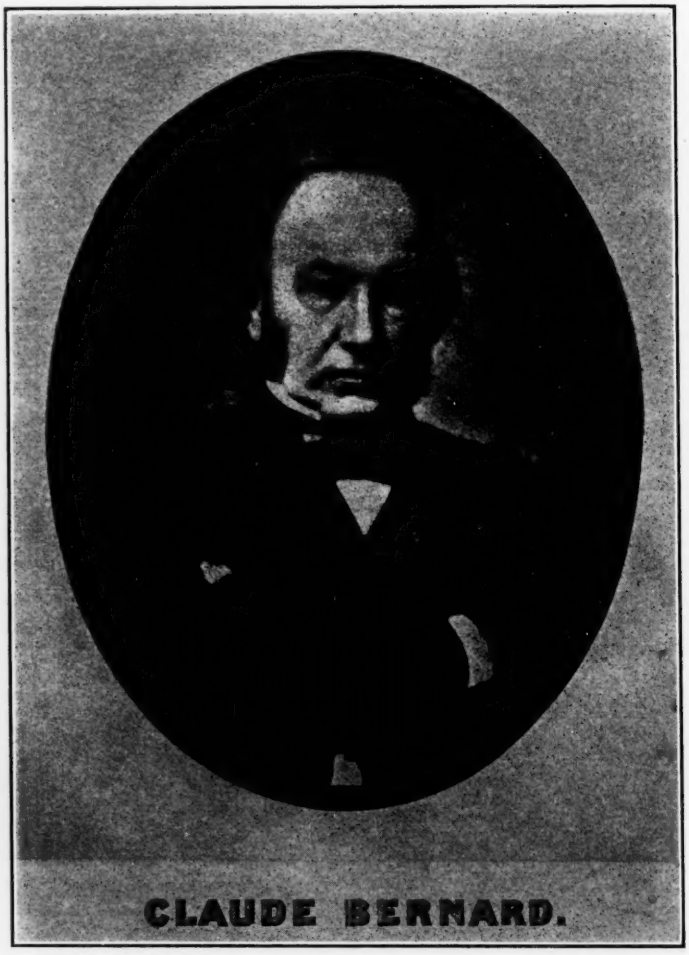
Claude Bernard was born in the little village of Saint Julien, department of Rhone, July 12, 1813. His father was a small land owner of the district and earned a comfortable living from the fruit of his vineyard. Bernard later came into possession of the estate and spent his vacations there, working out of doors among his trees and vines. He describes it thus:

> My dwelling is on the hill slopes of Beaujolais which look toward the Dombe. The Alps give me my horizon and when the air is clear I catch sight of their white summits. At the same time I see spread out before me for two leagues the prairies of the Saône. The slope on which I dwell is surrounded on all sides by vineyards stretching away apparently without limit; these would give the country a monotonous appearance were not this broken by wooded valleys and brooks running down from the mountains to the river. My cottage, situated though it is on a rise, is a very nest of verdure, thanks to a little wood which shades it on the right and to an orchard which flanks it on the left; a great rarity in a land in which they stub up even the coppices in order to plant vines.

Bernard and a sister were the only children. He was apparently a bright child, for the curé made him a choir boy and taught him Latin. Later, he went to the small Jesuit college at Villefranche and from there went to Lyons, where he soon left school to enter a practical pharmacy. At first he received only board and lodging for his services, but soon his manual dexterity won for him a small salary. He remained here two years, but his employer's mode of business made him sceptical of medical and pharmaceutical practise of the day as shown by the following story related by Sir Michael Foster.

> As was usual at that epoch the clients of the shop, especially the old women of the outlying vilages, made a constant demand for a syrup which seemed to cure everything; and Bernard, to his astonishment, found that this favorite syrup was compounded of all the spoilt drugs and remnants of the shop. Whenever Bernard reported a bottle of stuff had gone wrong, "Keep it for syrup," replied the master; "that will do for making syrup."

Bernard had literary aspirations, being especially attracted toward the drama, and spent much of his time at the Théâtre des Célestines. He wrote a vaudeville comedy entitled "La Rose du Rhône" which was accepted and attained a fair degree of success. Thus encouraged, he started in earnest to write a five-act historical drama in prose and determined to seek his fortune in Paris. On reaching the city, in 1834 when



CLAUDE BERNARD.

he was twenty-one years old, he presented his manuscript of "Arthur de Bretagne" with a letter of introduction to the great critic, Saint-Marc Girardin, who received him kindly and saw that the work possessed merit, but, knowing the uncertainties of a writer's life, suggested that Bernard take up some work whereby he could make a living. Hearing of his former pharmaceutical training, Girardin suggested that he study medicine. Bernard followed the suggestion and, for five years, applied himself to the work. He was especially interested in anatomy and

physiology. Anatomy, at this time, was well advanced and scientifically presented but physiology consisted of a mass of uncorrelated and inexact data.

His father died during this period, having lost most of his fortune before his death, and left Claude to depend on his own resources. He lived frugally and payed his fees with money earned by giving lessons. He was retiring, thoughtful, awkward in manner and impressed neither his fellow students nor his professors as being brilliant or liable to a great career. Only in the dissecting room did he attract attention by his careful and beautiful dissections.

In 1839, after serving as "externe" at the hospitals, he was made "interne" and appointed to work under Magendie, who was one of the physicians at the Hotel Dieu and professor of medicine at the Collège de France. The professor was allotted a small, dark room at the college for conducting research and was allowed a "préparateur" to assist in research and in experiments conducted to illustrate the lectures. He soon noticed Bernard's skill in dissection and appointed him his "préparateur." With this appointment, Bernard's career as experimental physiologist began. A glance at the state of physiology at this time will show the great odds against which he was about to work.

The spirit of present-day research was only beginning to be allowed full play. Harvey, early in the seventeenth century, opened the way for the application of experimental methods to physiological inquiry by his observations leading to the discovery of the circulation of the blood; but the vitalistic theory had impeded, at every step, the attempts to study living organisms. Slowly, this theory was losing ground and physico-chemical explanations substituted.

The spirit of progress was most apparent in Germany. Liebig had recently opened at Giessen the first public laboratory for chemical research. Wöhler had made urea from ammonium cyanate, thus destroying the old vitalistic argument that life was necessary to form organic from inorganic substances. Johannes Müller was the foremost physiologist. He was a vitalist, but only in a modified degree much more acceptable than Haller and his pupils. He believed in the necessity of recognizing a vital force, but maintained it was not independent of certain conditions. He did not depreciate the value of the experimental method in discovering physiological truths, as is shown by his own work and that of his pupils, among whom Ludwig, DuBois Raymond and Helmholtz, soon to be the foremost physiologists in Germany, were just beginning their careers.

In England, Hall, Reid, Sharpey and Bowman were advancing the science by experimental methods.

France had looked too much to her own scientists for the words of progress and was far behind her neighbors. Cuvier and Bichat were

especially popular. Cuvier, a morphologist and an ardent vitalist, was supreme and depreciated any attempt to explain or solve physiological problems by physico-chemical means. Bichat, though long dead, was very powerful and his explanations which were finally to overthrow the vitalistic conception had been misunderstood and misapplied to overemphasize it. Many scientists of the time asserted that living organisms could not be subject to exact experimentation.

Magendie was the foremost physiologist in France and believed in a modified vitalism. While he paid his respects to vitalism by admitting that some of the phenomena of life were beyond the scope of experimental investigation, he realized that physico-chemical explanations could solve many problems of physiology. Disgusted with the empty discussions of the vitalists, he went to the other extreme and threw his energies entirely into experimental study without thought or plan, and though his accomplishments were many, they fell far short, considering the time spent and energy consumed.

Bernard saw the fallacies of each line of endeavor and, at the outset strove to use all his powers of theoretical and practical reasoning, together with careful manipulation and observation. Besides his work at the college, he gave a course of private lectures and spent the remainder of his time at research, usually in some temporarily improvised private laboratory or in the chemical laboratory of some one of his friends. There was no room for his private research at the Collège de France.

In May, 1843, he published his first communication: "Recherches anatomiques et physiologiques sur la corde du tympan, pour servir à l'histoire de l'hemiplégie faciale," followed in the same year by his doctor's thesis—"Du suc gastrique et du son rôle dans la nutrition." The work on the chorda tympani nerve, suggested by Magendie's work on nerves, started a long series of similar studies. This was typical of his analytical and logical reasoning. He proceeded, step by step, in his experiments to their logical conclusion or until an observation suggested a separate line of inquiry which seemed to be more fruitful. His thesis on the gastric juice was also the first of a series which led to his great discovery of glycogen and the glycogenic function of the liver. The main result of this thesis was that cane sugar, injected into the blood, was excreted unchanged; but sugar which had previously been acted upon by gastric juice was not excreted when injected, but was retained and used by the tissues. These two pieces of work illustrate Bernard's line of thought. He was always interested in the action of the nervous system on the chemical changes involved in nutrition and worked from both the physiological and chemical aspect of the problem whenever possible.

In studying the difference in the digestion and nutrition between carnivora and herbivora, he noticed that fat fed to rabbits was digested

and absorbed much lower down than was the case when it was fed to dogs, and soon found that the variation was due to the different points of entrance of the pancreatic duct into the intestine in the two animals. This led to a long series of experiments on the function and properties of the pancreas. He showed for the first time that the pancreas and not the stomach was the chief organ of digestion and that the gastric juice merely started the digestion which was completed by the more powerful pancreatic juice. Its three-fold function for digesting proteins, fats and carbohydrates was also demonstrated. For this work, which was reported in 1848–9 and published complete in 1856, Bernard was awarded the prize of experimental physiology by the Académie des Sciences and was introduced to the scientific world as a physiologist of remarkable ability and great promise.

The story of the discovery of glycogen, which revolutionized prevalent biological theories concerning functions of the organs and differences between plant and animal metabolism, is interesting in showing how a quick, alert mind can "grasp the hints that Nature gives" and advance, step by step, to a final realization of the complete truth.

The prevalent view concerning the differences between plant and animal metabolism had been proposed by Dumas, the chemist, and Boussingault, the agronomist. They showed that plants build up complex organic compounds from inorganic substances and animals, by feeding, take the complex compounds already formed and break them down to simpler ones. Animals might modify them, but never make them more complex. There was a complete cycle in which compounds were built up by plants and broken down by animals. While this was the prevalent view, there were some strong minds who opposed it. Liebig confirmed Huber's old observation that bees, fed on sugar alone, produce wax and showed that fattening geese accumulate fat in excess of the fat fed.

Bernard proposed to trace the successive steps by which the various food-stuffs are transformed in the body and chose sugar as the subject for his first investigation because it seemed liable to the simplest explanation. The other foodstuffs were never investigated. He was early interested in diabetes and wished to find the cause for the excess of sugar in the blood and thereby assist in working out a remedy. His plan was as follows:

He had shown that cane sugar must be changed before it can be retained by the blood. Tiedemann and Gmelin had proved that starch is changed to sugar before it is absorbed from the alimentary tract. This indicated to him that all carbohydrates enter the blood as simple sugars. Where was this sugar destroyed? If he could find the tissues that caused the destruction and by some means decrease their activity, the blood would become overloaded with sugar and experimental dia-

betes would be produced. Thus, the discovery which he made was not the result of a "haphazard dive in Nature's full pocket" but came from a carefully planned experiment. As was often the case, the investigation did not yield the expected results, but something equally valuable.

He fed a diet rich in sugar to a dog, killed it at the height of digestion and examined the blood leaving the liver by way of the hepatic vein to see if the liver caused a destruction. An abundance of sugar was found here. To see if this was the sugar which had been fed, the experiment was repeated, giving the dog only meat. To his great surprise, an abundance of sugar was again found in the hepatic vein and very little in the blood from the other organs. He immediately divined the truth that the liver makes the sugar which was found in such large amounts. Repetition of the experiments with many modifications always produced the same results. The sugar was shown to be dextrose. Different animals showed the same phenomenon. These results were published in 1849–50, when he described the sugar production by the liver as similar to a secretion and not influenced by the kind of food eaten.

These observations, confirmed by others, established the glycogenic function of the liver; that is, they proved that the liver produces sugar by a mechanism similar to secretion. Going further, he showed that the sugar is not made from substances in the blood flowing through the liver, but from a substance present in the liver tissue. This was demonstrated by washing out all the blood and sugar from an isolated liver. After letting it stand for some time in a warm place, more sugar could be washed out with water. Boiled liver tissue did not react in this way, but if a small amount of fresh liver decoction was added to the boiled tissue, sugar was produced as before. This experiment showed that the sugar was formed by enzyme action from something present in the liver tissue. He isolated this substance and showed it did not give the tests for dextrose, but was easily changed into it by fermentation. These results were announced to the Académie des Sciences on September 24, 1855. Two years later, he obtained the substance in a pure state and gave it the name "glycogen." Analysis showed it to be a carbohydrate.

Bernard believed the formation of glycogen in the liver to be a vital process, but the formation of dextrose from glycogen to be a simple enzyme action independent of life. This was contrary to the teaching of the time, for all enzyme actions were considered to be inseparable from the living cell. He showed that the blood contains an enzyme capable of forming dextrose from glycogen and suggested that a nervous control of the circulation governs the sugar formation. Comparisons were drawn between the formation of glycogen and sugar in the animal body and starch and sugar in plants.

While work was continued along this line, the fundamentally im-

portant results have been mentioned above. Other experiments and writings confirmed, extended and defended his views. Bernard had made a great discovery and pushed it to the end and did not have to suffer the humiliation so often falling to the lot of a pioneer who pronounces a great fundamental truth and is outstripped by his contemporaries in producing proofs and developing details. Though it took several years to work out all the details, he always kept the lead.

This discovery supplied much that had been obscure concerning the sugar metabolism in the body and the functions of the liver, and greatly influenced general biological thought. It overthrew the idea that animals can not construct but only destroy products built up by plants. It broke down the prevailing theory that each organ has only one function. Previous work had shown that the liver produces bile and the pancreas and stomach furnish digestive juices. Nothing more seemed left to be learned except the function of the spleen. The discovery of the second function of the liver destroyed the bonds which the theory of functions had thrown around the biological thought of the time and encouraged more work in this field. The introduction of the idea of an internal secretion which was poured into the blood to assist in the normal nutrition of the body has been very productive and still fills the minds of physiologists and bids fair to produce some of the most valuable contributions to modern physiology.

Glycogen was soon found in all the tissues and quantitative relations were investigated. Others have contributed but little new to the subject and Bernard's ideas stand to-day as he expressed them then.

> He, in the matter of glycogen, not only laid the very first stone, but left a house so nearly finished that other men have been able to add but little.

During this work, Bernard discovered the remarkable fact that a puncture of the fourth ventricle of the brain causes temporary diabetes. This, like other of his discoveries, was not happened upon accidentally, but was the result of logical reasoning concerning the nervous control of the sugar production by the liver, which he assumed to be a typical internal secretion. He found that cutting the vagus nerve stopped the sugar production and reasoned that stimulation of the nerve should lead to increased production. Being unsuccessful when all the ordinary means of nerve stimulation were used, he resorted to an expedient which he had noted previously, that a marked stimulation occurred when the point of origin of the nerve in the brain was punctured. In this case, an over-production and excretion of sugar was obtained. Here, as in a number of instances, a wrong view led him to an important discovery for he soon showed that the vagus is not a true secretory nerve governing the hepatic sugar secretion.

This illustrates one of Bernard's important characteristics. He de-

veloped a line of theoretical reasoning to its fullest and, by watching his experimental evidence, could grasp whatever facts showed themselves unbiased by the reasoning which had suggested the experiment. He emphasized imagination and preconceived theory when used in their proper places and used to say:

> Put off your imagination as you take off your overcoat when you enter the laboratory; but put it on again, as you do the overcoat, when you leave the laboratory. Before the experiment and between whiles let your imagination wrap you round; put it right away from yourself during the experiment itself, lest it hinder your observing power.

His discovery of the vasomotor nerves was hardly less important than the discovery of glycogen. These nerves control the circulation of the blood by causing the muscles in the walls of the blood vessels to increase or diminish the bore thus allowing more or less blood to flow through at one time. The nerves belong to the sympathetic system, that is, they are not under the control of the will but stimulated by sensory impulses. The part played by him in this work was different, for he did not realize the importance of his discovery. As usual, he was looking for something else, and did not immediately turn aside to follow the new line of work.

The knowledge of the blood vessels at this time was very limited and inexact. Johannes Müller, the foremost physiologist in Germany, in his classical work on physiology in 1838, concluded that the arteries did not possess a muscular coat but only physical elasticity. He was entirely unprepared for the idea of vasomotor nerves. The sympathetic nerves had been traced to the blood vessels and some thought they should have something to do with the circulation. Stilling introduced the word "vasomotor" in arguing from theoretical grounds that the circulation must be governed by nerves not subject to the will, but influenced by sensory stimuli. In 1846, Kölliker discovered that plain muscle was made up of minute spindle-shaped cells either in clumps or scattered. This cleared up the doubts concerning the muscle coat of the blood vessels. The way was now open for the proof of the vasomotor nerves, but no one saw it.

Bernard proposed to study the influence of the nerves on animal heat, and began by attempting to ascertain the effect of cutting a sympathetic nerve on the temperature of that part of the body affected by it. He conceived that the action of the nerve, if any, would be in governing the chemical changes involved in heat production, and expected to find a section of the nerve would cause a lowering of temperature. Working on the cervical sympathetic nerve in a rabbit, he was astonished to find an increase instead of a diminution in heat on the side of the head where the section was made. He reported:

All the part of the head that becomes hot after section of the nerve becomes also the seat of a more active circulation. The arteries seem fuller and appear to pulsate more forcibly; this is distinctly seen in the case of the rabbit in the vessels of the ear.

He reserves for further consideration "whether the vascular changes are the cause or the effect of the rise of temperature." While the work was published as experiments on animal heat, it is the first clear and decided experimental proof for the vasomotor functions of nerves. The operation had been performed for one hundred and fifty years and the constriction of the pupil of the eye had been noticed, but the increased heat and the dilatation of the arteries had never before been observed. With this experiment, the true knowledge of vasomotor nerves begins.

This discovery caused a great stir in the scientific world and several investigators proceeded to work on the subject independently. Brown-Sequard proposed the correct interpretation of the phenomena that section of the nerve caused a dilatation of the blood vessels and the dilatation allowed increased blood flow which resulted in an increase in temperature and irritability. Bernard held continually that part of the heat effect might be due to the influence of the nerves on the chemical activities in the tissues.

Several years later, working on the submaxillary gland, Bernard observed that the blood coming from the gland was bright red, like arterial blood when the chorda tympani nerve was stimulated, and that it was dark, venous and small in quantity when the sympathetic nerve was stimulated. Thus, he showed that the chorda tympani is a vasodilator nerve causing dilatation and increased blood flow, while the sympathetic is a vasoconstrictor nerve. This effect was shown to be true for other glands. This was the first clear announcement of the presence of vasodilator and vasoconstrictor nerves.

Other lines of work occupied his attention, but the results do not possess such fundamental value as those described above. He worked on the physiological effects of curare, the arrow poison of the South American Indians. Carbon monoxide poisoning was explained as due to a stable combination of the gas with the red blood corpuscles. This explanation was made before respiration had been explained as due to an unstable combination of oxygen with the hemoglobin of the red blood corpuscles. He presented a proof against the spontaneous generation of life when that question was a vital issue in the scientific world. He carried out some work on fermentation opposing Pasteur's views that the living cell is necessary, thus anticipating Buchner's proof by twenty years.

Bernard began work when opportunities for research were scarce and his chosen field was looked down upon and scoffed at, but he per-

sisted despite the obstacles in his way. In 1847, he was appointed a deputy at the Collège de France and a career seemed assured. He now could work in an official laboratory. He said at the beginning of his lectures:

> Scientific medicine, gentlemen, which it ought to be my duty to teach here, does not exist.

Four years later, he was much disappointed in his career and thought of giving up scientific work and going into private practise. Unhappy domestic relations made matters worse, for his wife had no sympathy for his scientific endeavors. He was, however, beginning to be recognized as a coming man in science and was given the newly created chair of general physiology in the University of Paris at the Sorbonne. This was the first honorable position for him to occupy and his devotion to science was now assured. In the same year, he was elected to the Academy of Medicine and Surgery. In 1855, Magendie died and Bernard took his place as professor at the Collège de France.

The lectures were not specified at the college, so he usually chose some topic on which he was working and developed it, from lecture to lecture, illustrating with old and new experiments. He used his lectures to make known new facts and new or corrected and extended views. The reports which were made to the Académie des Sciences and the Société de Biologie were very brief and incomplete. Only in his published "Leçons" is a full account given of his experiments and results, many of which are found there alone. They were reported by one or another of Bernard's students, revised by him and published. These are his greatest written contributions. The series began with "Leçons de Physiologie expérimentale," published in 1855, dealing with the physiology of sugar and the glycogenic function of the liver. He published seventeen volumes in all.

In the winter of 1862–63, he was bothered with an abdominal trouble, probably appendicitis, from which he did not recover for five or six years. Part of the time he spent at his old home at St. Julien tending his gardens and living out of doors. Here he had an opportunity to broaden and generalize his ideas and write an "Introduction to the Study of Experimental Medicine." In his later years, his thinking became more general. He always tried to show the true spirit of physiological inquiry and to realize the general aspects of the whole field. This is well shown in his lectures on the phenomena of life common to plants and animals.

In 1864, he visited court and greatly interested Emperor Louis Napoleon, who entered into a lively discussion with him which lasted for two hours, and was so well pleased that he ordered his minister of public instruction to see that he had whatever he wanted. Bernard obtained

in this way two well-furnished laboratories, one at the Sorbonne and the other at the Jardin des Plantes, where he held the chair of general physiology. Thenceforth, his life was full of distinction and honor. In 1868, he was elected to the Académie Française and became one of the "Immortals."

He was separated from his wife and children and lived by himself on the Rue des Écoles, opposite the chief entrance to the Collège de France. He was always retiring and shrank from social distinctions. Foster thus describes him:

> Tall in stature, with a fine presence, with a noble head, the eyes full at once of thought and kindness, he drew the look of observers on him wherever he appeared. As he walked in the streets passers by might be heard to say, "I wonder who that is; he must be some distinguished man."

He was a great friend of Berthelot, the chemist, and Renan, the philosopher, both of whom were his colleagues at the college. His pupils worshiped him.

Bernard was seized by a chill in the laboratory, developed an acute affection of the kidneys, and died, after a lingering illness, February 10, 1878. He was accorded a public funeral at the expense of the state, an honor previously bestowed upon none but statesmen, princes and soldiers. France paid her highest tribute to this quiet man of science who had contributed much, by fact and inspiration, to the advancement of the knowledge of physiological phenomena.

What were the attributes of mind and character which made Bernard a genius as an investigator?

His conscientious adherence to truth at all times need not be emphasized, as that is necessary for all true scientists, great or mediocre. His greatest attribute may have been his fruitful imagination, always under control, active before and after an experiment and asleep when observations were being made. Imagination is necessary to produce original hypotheses and it must be tempered with judgment to produce hypotheses capable of being put to experimental test. Bernard considered none but those of practical value, capable of being proved right or wrong. His readiness to turn aside from a line of research to take up a new inquiry suggested by some observed fact was remarkable for its frequent though opportune use. When to turn aside and when not to do so demands the mind of a genius for solution.

A thing of practical importance and of great value to him was his manual dexterity. In such experiments as some of his, a poor dissection or bunglesome manipulation might easily have complicated the experimental conditions so that the results would have been difficult of correct interpretation and a false step at any point might have led him astray.

It has been said that Bernard has not influenced scientific thought and stimulated investigation as others have, for he so nearly completed the work suggested by his great discoveries. However true that may be in a limited sense, the statement is unjust, for, as with all important scientific discoveries, the effect produced indirectly on scientific thought can not be estimated. He was the first to prove beyond a doubt that animals can build up as well as break down complicated products in the course of their normal nutrition. Few ideas have been more stimulating than this and it undoubtedly greatly influenced thought which subsequently led to the proof of the synthesis of fat and the discovery of the complicated process of protein metabolism whereby protein foods are broken down and built up in the body. Destruction of the theory of functions encouraged further work on the various organs of the body. Since then, many valuable facts have been produced showing the close interrelation of functions of the organs and their interdependence on each other for normal activity. The discovery of the vasomotor nerves opened up an entirely new conception of the regulation of circulation and temperature. It has been of untold value in explaining physiological and pathological phenomena concerning this, one of the most fundamentally important functions of the body. Medical science has applied it to practical problems and made the knowledge of vasomotor activity indispensable to the practising physician.

Taken altogether, his work produced results which greatly advanced knowledge of physiological phenomena, placed physiology among the great sciences, and opened new lines of inquiry which yet promise to bear fruit of which his fertile imagination could not conceive.

THE GENERAL PHYSICO-CHEMICAL CONDITIONS OF STIMULATION IN LIVING ORGANISMS

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IT is customary to say that *irritability,* or the capability of responding to stimuli, is an essential characteristic of living beings. Whether this is true or not of the lowest organisms—certain bacteria or the filterable viruses—there is no doubt that it is preeminently so of the higher, and especially of those leading free and active lives, like most animals. If this were not the case it is difficult to see how such organisms could maintain themselves in their surroundings and continue to behave as living beings—*i. e.,* show their characteristic activities, grow, and eventually reproduce themselves. At least it is clear that in order to do this they must *react* to the changes continually taking place in their particular environment in such a way as to favor their continued existence in that environment; if, for instance, any animal failed to respond to the presence of food—material that can serve it as source of energy—by capturing and incorporating enough to replace its own normal loss of substance, quite obviously its life would soon come to an end. And if it reacted in the same way to the poisonous or otherwise injurious substances in its surroundings as to food, and incorporated both classes of material indifferently, the same result would follow. Evidently there is needed some power of active and selective response to the changing conditions of the environment if the living organism is to continue to live; it must preserve a certain equilibrium with its surroundings; the materials and energy which it appropriates from those surroundings must in the long run at least equal those which it inevitably loses to them in the normal course of its vital processes. This is the physiological interpretation of Spencer's dictum that all life involves a continued adjustment between internal and external relations. The organism must continually alter its activities in correspondence with altered conditions in its surroundings, and in such a way as to preserve this adjustment—avoiding conditions likely to disturb or destroy the vital equilibrium and tending to place itself in those favorable to its continuance. Accordingly, we may say that living organisms in general, and especially animals, exhibit two broad classes of reactions, first those of a defensive or protective kind, including avoiding reactions and inhibitions of various kinds, and second, the more active group of what we may call self-seeking or acquisitive reactions; of these the chief are the reactions of food-seeking,

by which the necessary supply of transformable energy and of building material is secured. Both kinds of reactions are equally responses to stimulation; and both are alike physiologically indispensable. In fact, the characteristic self-conserving or regulatory power of organisms, without which they could not continue to exist, depends essentially upon their ability to respond in this way, *i. e.*, upon their irritability.

It is thus apparently not difficult to understand the general biological significance of irritability. What is still largely obscure, however, is the physico-chemical nature of the mechanism which renders possible the response of an organism to stimulation. Physiological experimentation has enabled us to simplify the problem to some degree. We find that not only the intact living organism, but many of its isolated tissues and even cells, react in characteristic ways to stimulation. This is especially true of the tissues that subserve the motor activities of the animal, the muscles, nerves and sense organs. Thus the problem of the nature of the stimulation-process becomes one of the general problems of cell-physiology, and may be stated as follows: What are the essential physico-chemical peculiarities that render the irritable elements of these living tissues so sensitive to stimulation? and what is the physico-chemical nature of the process of stimulation itself? These are the questions which I shall attempt briefly to discuss in this paper. Any answers which can be given at present are incomplete and in part provisional. But recently some definite progress—as it seems to me—has been made toward their solution, and I shall try in what follows to give some account of this recent work and of the more important general conceptions to which it has led.

We have first to define more clearly what we mean by "stimulus" and what by "response." We find on reflection that it is a difficult matter to formulate definitions that are at once exact enough and comprehensive enough to characterize adequately all of the highly varied phenomena included under these terms. We may perhaps best define a *stimulus* as some change of condition that arouses a previously quiescent tissue or organism to activity, or appreciably modifies the activity of one already active; and the response as the resulting activity or change of activity. In many cases the response may be *negative* in kind; *i. e.*; the previous activity may be decreased or completely arrested; inhibition is in fact a very frequent mode of response and one perhaps fully equal in importance to the more positive or active modes as a means of biological adjustment. But what is perhaps the most characteristic peculiarity of the relation between stimulus and response is the fact that there is, broadly speaking, no definable relation of an energetic kind between the two. One of the most striking and distinctive features of stimulation is that an external event or change of condition which causes directly a very slight alteration in the irritable system or organism may yet arouse in

the latter a process or series of processes in which the transformation of energy may be almost indefinitely large—out of all proportion to the exciting stimulus. We have therefore first to inquire into the general nature of the conditions that render possible such disparity between the stimulus—considered by itself as a particular chemical or physical process acting upon the irritable tissue—and the resulting special activity or response on the part of the tissue itself.

As all know, an irritable tissue like a nerve or muscle may be aroused to activity under the most various conditions; the effective stimulus may be an electric shock, a chemical substance, the action of light, change of temperature, loss of water, mechanical impact; and the tissue gives the same response to all of these. Now it is clear that such a stimulus can only act as some kind of a *releasing* agency—what Ostwald calls *Anlass*—which sets going some process all of the necessary conditions of which are already present, but which is held in check by some restraining condition which the releasing agency removes—as when a gun is fired, or an alarm-clock set off, or a mine exploded by the pressure of a button—which closes an electrical circuit, thus enabling a spark to pass, which raises the temperature of the explosive to the critical point. The connection between *Anlass* and resulting event may be highly indirect, and there need be no resemblance or other relation than that of interconnection between the two. In all cases the system is, as it were, "wound up"; the potential energy is there, ready to become kinetic; once the process is started or activated by the releasing event, it proceeds of its own accord to its conclusion, *i. e.*, till a second state of equilibrium is reached. In the case of a living irritable tissue or organism we are evidently dealing with a physico-chemical system belonging—as regards the relations between the initiating conditions and the resulting process itself—to this general class. If we press the end of a nerve connected with a muscle, or pass through it an electrical current of sufficient intensity for a sufficient length of time, or dip it into a solution of some appropriate chemical substance, there is initiated at the site of stimulus a "physiological" process which is propagated with unaltered intensity along the nerve to the muscle and there calls forth a complex variety of interdependent physical and chemical changes, of which the contraction is the most conspicuous and physiologically important. Thus a process specific to the tissue, unique and obviously highly complex, is initiated by the relatively insignificant change which the stimulus causes directly. We ought particularly to note that in any special tissue the physiological process remains the same in kind, whatever the nature of the stimulus. The latter merely causes some critical or releasing change which initiates the physiological sequence of events; the latter then proceeds automatically in its characteristic way to its conclusion.

Let us now consider more particularly the physiological part of the

whole series of processes—*i. e.*, the response of the living system to stimulation. First we must note that since in any special case the response as a whole is constant, all of its single component stages or separate processes must also be constant, both in their character and their interconnections. There must therefore be some one constant initial process which is directly caused by the external event or stimulus, and upon which the others automatically and inevitably follow. This initial process thus constitutes the critical or activating event in the physiological sequence. It alone is directly dependent on the stimulus; the others are dependent upon it. What is remarkable is that it should be produced by such a variety of different agents. The problem first to be considered may therefore be put somewhat as follows: What is the nature of the initial change produced in the irritable living tissue by the action of the external agent, and how does it happen that it can be caused by such diverse agencies? This problem has evident relations to a wide group of physiological and psychological problems; thus the question of the basis of the "specific energies" of the special sensory apparatus belongs here. In this case also the response—the conscious affective state or sensation—is distinctive and its quality independent (within certain limits) of the character of the stimulus. This is in fact characteristic of all cases of stimulation. How this can be possible I shall now attempt to indicate.

Let us take the case of the simplest of the irritable tissues of higher animals, one in which the excitation-process occurs in a highly characteristic form, but unaccompanied by highly specialized physiological effects like contraction or secretion. Such a tissue is nerve. What are the essential features in the response of this tissue to stimulation? It is first to be noted that the process set up by the external stimulus is *self*-propagating. The disturbance, whatever its nature, which originates at the point of stimulus is of such a kind that it imparts a stimulus to the adjoining regions of the nerve beyond the original point of stimulus; these on becoming active stimulate the next stretch of nerve, and in this way the state of excitation passes along the entire nerve to its termination. Evidently there is an active change of some kind, forming an essential component of the local nerve process, that acts as stimulus to adjoining regions. Now there is no mechanical change in a nerve as the impulse passes, little or no production of heat,[1] apparently a slight physical or chemical change involving a loss of carbon dioxide; but none of these is in itself sufficient to act as stimulus. There is, however, another definite physical change which has this power: namely, the electrical variation—the bioelectric process or action-current—which always accompanies the activity of a nerve or indeed of any other irritable tissue.

[1] Such, *e. g.*, as causes the transmission of the chemical change along a train of gunpowder.

The stimulated region undergoes a rapid change of electrical potential, becoming externally negative relatively to its resting condition; the neighboring still inactive regions being thus positive relatively to the active region, the conditions for the flow of an electrical current between stimulated and unstimulated regions arise. This current is undoubtedly of sufficient strength to stimulate the tissue for some distance beyond the immediate site of stimulation. The voltage of the action-current of frog's nerve is at least thirty millivolts; and a current between platinum electrodes two or three centimeters apart differing in potential by this degree is amply sufficient to stimulate an irritable nerve. The conditions when the two regions of different potential are not externally applied electrodes but portions of the nerve itself are not essentially different; in either case a current flows along the nerve; and if this current is intense enough and arises suddenly enough it must stimulate the latter. There is thus reason to believe that the electrical variation accompanying stimulation is the main condition of propagation of the excited state. This conclusion is supported by various experimental facts; for instance, it is found that the rate of development of the electric variation and the rate of passage of the impulse are influenced to the same degree by changes of temperature, and by certain chemical substances such as the anesthetics. There are various other facts pointing in the same direction, and there are also certain difficulties in the way of this conception; but into these we cannot enter here. The fact remains that the electrical variation is the only known peculiarity of the local process that can account for its self-propagating character; and recent determinations of the minimal current needed for excitation indicate that the bioelectric currents are of sufficient intensity to serve as the basis for this propagation.

It is clear that propagation of the state of excitation from the immediate site of stimulus over the entire cell or nerve fibre is indispensable to stimulation of any irritable element as a whole by any local stimulus; so that if the above view is correct we must regard the electrical variation as perhaps the most essential feature of the stimulation process. If so, we can understand why the electrical current has such universal stimulating action. In passing a current through a tissue we are artifically setting up differences of electrical potential between different portions of the irritable elements, and according to the above conception this should always cause excitation if the current is strong enough and rises to its maximum with sufficient rapidity. That this is in fact the case needs no emphasis. The electrical current is recognized as the most universal form of stimulus; and all irritable cells and elements, virtually without exception, respond to its action.

We conclude then that the critical or initiatory event in stimulation is an electrical change, consisting essentially in a sudden decrease in the electrical potential of the external surface of the irritable element at the

site of stimulation; a difference of electrical potential is thus set up between one portion of the irritable element and another. The problem thus becomes clearer: how is it possible that, *e. g.*, a slight mechanical pressure, or the action of a chemical substance or ray of light, may have this effect on an irritable tissue—*i. e.*, may cause a negative electrical variation and so stimulate? and why do electrical changes, of all the processes in nature, bear this distinctive relation to stimulation?

The answer to these questions is far from complete at present, and their consideration brings us at once to some of the most fundamental questions of general physiology. All of the evidence indicates that the bioelectric processes are of critical importance in the life of the cell; they are associated with the most various physiological activities, and accompany the process of stimulation in all irritable tissues; and it is clear that we must understand their controlling conditions before we are in a position to answer the above questions. Now there is one very general peculiarity of living cells which is intimately connected with their power of responding to stimuli—namely, the possession by the surface-layer of protoplasm of peculiar properties in relation to the diffusion of dissolved substances. Living protoplasm is an aqueous solution, chemically complex and containing a high proportion (10–20 per cent.) of colloidal substances, chiefly proteins and lipoids. Experiment has shown that not all soluble substances readily enter the protoplasm of living cells; thus neutral salts like NaCl, sugars and amino-acids (the chief elementary constituents of proteins) diffuse into unaltered cells with difficulty if at all; the surface-film of the protoplasm typically acts toward such substances as a semi-permeable membrane. It is for this reason that the cells of plants remain during life turgid or distended with water, often under high pressure. Osmotic effects, dependent on the semi-permeability of the protoplasmic membranes, are the direct cause of this turgor. The living cell, in other words, is typically enclosed by a modified protoplasmic surface-film or membrane, the plasma membrane, which allows water to pass readily but not dissolved substances of the above kinds. The presence of this membrane makes it possible for the dissolved substances within and without the cell to be very different in character and concentration, and upon this condition the integrity of the living cell undoubtedly very largely depends. We find in fact that when the cell dies many substances, confined during life within its interior, diffuse out into the surroundings; the plasma membrane loses its osmotic properties; the plant loses turgor, wilts and withers; analogous changes occur in animal cells, the colloids coagulate and the cell disintegrates. Conversely if we alter the plasma membranes by chemical substances (poisons), so as irreversibly to destroy their semi-permeability, death inevitably follows. Semipermeability is thus for many if not for all cells an essential condition of continued life.

Semipermeability also forms the condition of another fundamentally important property of the living cell, namely, its possession of highly characteristic electrical properties. Physical chemists find in general that if a solid film or other partition consisting of any sufficiently impermeable material—*e. g.*, glass, an organic membrane or a precipitation membrane of copper ferrocyanide or similar material—is interposed between two different solutions containing electrolytes which are thus prevented from mixing, a permanent difference of electrical potential arises between the two solutions. The same appears also to be true of the protoplasmic surface-films or membranes. Apparently, so long as the plasma membrane preserves its normal semi-permeability there exists a considerable difference of electrical potential between its external and internal surfaces—*i. e.*, between the exterior and the interior of the cell—dependent on the difference in composition between the protoplasm and its surroundings. Thus the exterior of a resting muscle cell or nerve fibre is always found positive relatively to its interior. But with the loss of semipermeability at death this potential difference—or demarcation-current potential—also disappears. It thus evidently depends upon the semipermeability of the plasma membrane; and since this electrically polarized condition of the membrane is undoubtedly a factor of prime importance in many cell activities, including stimulation, we see again how physiologically essential a property this semipermeability of the plasma membrane may be.[2]

Further, there is little doubt that this property is one of the essential conditions on which the possibility of stimulation depends. Nernst has shown that an electric current stimulates by changing the concentration of ions at the semipermeable membranes of the irritable tissue; this is equivalent to producing a potential-difference or electrical polarization between the outer and inner surfaces of the membrane. The normal pre-existing or physiological potential difference is thus altered—in stimulation is typically diminished—and when this change is sufficiently extensive and rapid the tissue gives its characteristic response. Now these polarization-effects depend on semipermeability, since if the membrane allowed all ions to pass freely the differences of concentration in which the polarization depends evidently could not arise. We find in fact that the cell whose membranes have lost their semipermeability does not respond to stimulation. Such a cell is "dead"; this however need not mean that all vital manifestations have ceased; many metabolic processes may in fact continue in dead cells and lead to far-reaching chemical transformation of the cell-constituents; such changes are called "autolytic." What is lost is the power of responding to stimulation; hence the automatic regulation of the vital processes ceases, and presently these

[2] *Cf.* my article on the rôle of membranes in cell processes in THE POPULAR SCIENCE MONTHLY for February, 1913.

come to an end. We have seen that such a cell has also lost the characteristic vital potential difference between exterior and interior. Response to stimulation thus depends on semipermeability, which implies polarizability of the membranes bounding the irritable cells or elements. This conclusion is one of far-reaching importance, because it localizes the primary change in electrical and hence in other forms of stimulation at the plasma membranes. Some *membrane-process* forms the first stage of the response to stimulation. The membrane is thus not to be regarded as a mere passive diffusion-preventing barrier between living substance and surroundings, but as the essentially sensitive and controlling portion of the cell.

Although there is much evidence that the initial event in stimulation is a surface-process and involves a change in the chemical and physical properties of the plasma membrane, the precise nature of this change is imperfectly understood at present. It seems, however, clear that it involves a temporary loss or lowering of semipermeability: *i. e.*, the osmotic properties of the membrane are altered, and along with these its state of electrical polarization. This change forms the condition of the other and more complex changes in the interior of the stimulated cell. Evidence of a temporary loss of semipermeability comes from a number of sides, and is seen in the irritable tissues of both animals and plants. Many motor mechanisms in plants depend on this change; *e. g.*, the movements of the sensitive plant, of the Venus' fly-trap, the tentacles of the sundew, etc. Turgid cells arranged in special ways lose their turgor on stimulation and collapse; the resulting movements may be so rapid—*e. g.*, in the Venus' fly-trap—as to simulate muscular contraction. Yet the effect is undoubtedly due to a loss of water caused by a change in the osmotic properties of the plasma membranes.[3] Phenomena of just this kind are not seen in animal cells, where osmotic distension or turgor plays a less important part than in plants; but in gland-cells, many of which are under nervous control, closely similar changes follow upon stimulation. Water and dissolved substances are rapidly lost from the cells, which in many cases shrink at the same time. Electrical variations accompany these processes in both the plant and the animal, and are probably directly due to the change in the membranes. An especially clear parallelism between increase of membrane-permeability and stimulation as seen in the larvæ of the marine annelid Arenicola; these larvæ are minute worm-like organisms a third of a millimeter long, actively muscular, and swimming freely by their cilia. When brought into pure sodium chloride or other appropriate salt solution the muscles instantly contract strongly and the contraction is invariably accompanied by a

[3] The term plasma membrane is applied by some botanists to the entire layer of protoplasm between cell-surface and vacuole-surface. The most external surface-layer, to which ordinarily the term is applied, can not in fact be sharply separated from the inner protoplasm.

rapid loss of a yellow coloring matter from certain cells forming part of the body. Apparently any change of condition, chemical or other, that increases the permeability of these cells sufficiently to cause a rapid loss of pigment causes also strong stimulation of the irritable elements. It is possible to prevent the stimulating effect of the salt solution by anesthetics or by certain other salts, *e. g.*, calcium or magnesium chloride; and at the same time the change in the pigment-containing cells is also prevented. Rapid increase of permeability and strong stimulation thus show a definite parallelism. Other widespread phenomena, such as the refractory or inexcitable period shown by all irritable tissues immediately after stimulation, point in the same direction. There is indeed an unusually broad basis of biological fact for the inference that in irritable tissues the plasma membranes undergo a sudden and well-marked increase of permeability during stimulation—*i. e.*, lose their semipermeability for a brief time, the exact duration of which varies characteristically for different tissues.

Stimulation appears always to be accompanied by a change in the electrical properties of the irritable elements; and there is every indication that the characteristic negative variation or action current is an expression or consequence of the above change in the membranes. As already pointed out, any semipermeable partition or membrane separating two electrolyte solutions becomes the seat of an electrical polarization, whose degree depends on the nature and concentration of the dissolved substances and on the nature of the partition. Under these conditions any sudden increase of permeability—sufficient to abolish semipermeability—must have the same effect as if the partition were suddenly to disappear; the potential difference between the two solutions then falls to what it would be if no partition separated them. The variation in the electrical potential of the cell-surface during stimulation has in fact the characteristics that we should expect to find if just this change occurs. The electrical variation is always in the direction of an increased *negativity* of the stimulated region; similarly the dead or injured region where the membranes have lost their normal properties always becomes negative, only permanently instead of transitorily so. In stimulation the membrane-change is reversible, in death irreversible. But the *direction* of the transitory electrical variation of stimulation indicates a temporary change in the osmotic properties of the membranes of the same general nature as that associated with death or permanent injury.

We conclude therefore that during stimulation there occurs a temporary and well-marked increase in the permeability of the limiting membranes or protoplasmic surface-films; with this change is associated an electrical depolarization. Experiments with the class of substances known as anesthetics confirms this point of view. When present in

the proper proportions these substances render an irritable tissue irresponsive to stimulation. I have recently found that they also change the properties of the plasma membranes in Arenicola larvæ and sea-urchin eggs in such a way as to make them more resistant to increase of permeability under the influence of salt-solutions. A definite parallelism appears to exist; if we render the membranes more resistant to alteration than formerly, we render the tissue less irritable. This influence of anesthetics on plasma-membranes is a very general if not universal characteristic of living organisms. Thus the permeability of plant-cells to salts is decreased by these substances, as Lepeschkin and Osterhout have found, and Loewe has recently shown that artificial lipoid-impregnated membranes are similarly affected. These facts explain why anesthetics counteract the effects of stimulating agencies—which cause temporary *increase* of permeability; and since most anesthetics are lipoid-solvents, we are led to the conclusion that they cause their effects by changing the state of the lipoid components of the membrane; thus the properties of this structure are altered—particularly the readiness with which its permeability is changed by external conditions acting upon it.

Irritability would thus appear to depend on a peculiar state of the plasma membranes—one in which under slight variations of external conditions these structures undergo automatically a rapid and pronounced increase of permeability. A certain state of physico-chemical instability or lability of the protoplasmic surface-film seems to be the essential condition on which a highly developed irritability depends. Such a membrane appears to retain its properties unaltered only if the external and internal conditions remain approximately constant, *especially the state of electrical polarization.* If this latter is suddenly changed, as by an external even slight electrical disturbance, some hindrance to interaction seems to be removed, and a chemical process is initiated which instantly alters the character of the membrane and stimulation follows. This, or something closely similar, appears to be the condition in tissues whose irritability is sensitive and rate of response rapid. Apparently all variations occur in the rate at which this change takes place. The electrical variation, whose rate of appearance and subsidence is an index of the rate of the surface-change, is highly rapid in some tissues and slow in others. Thus it lasts for about a thousandth of a second in a frog's motor nerve, and for several seconds in a slowly responding tissue like smooth muscle; and all intermediate conditions are known to exist. These variations in the speed and sensitivity of the response depend primarily on the specific peculiarities of the plasma membranes of the different tissues. What determines the differences between different irritable tissues and organisms in these respects is a subject for future investigation.

These peculiarities of the plasma membranes enable us to understand

why the same tissue may respond in the same way to so many different stimulating agencies. Any agency that alters the surface-film to a degree and at a rate sufficient to cause a critical change in its electrical polarization will stimulate. The membrane may be directly altered by mechanical agencies, or by heat or the direct action of chemical substances; or it may contain photosensitive substances and hence be sensitive to light, or special chemical substances and show a specific chemical sensitivity. Whatever alters it in such a way as to change, even momentarily and locally, its permeability and electrical polarization to the critical degree may thus stimulate, *i. e.*, may originate a depolarization which spreads and affects the entire cell. The response which then follows is independent of the nature of the stimulating agency and is determined by special peculiarities of the irritable tissue itself.

The processes which take place in the interior of the stimulated cell are too various and complicated to be considered here. Their nature depends entirely on the specific peculiarities of the cell, and any general characterization is impossible. Usually there is an increase of oxidations and hence of heat-production—in addition to the special physiological manifestation which is evoked—but this is not always the case; thus in nerve, although there is increased loss of carbon dioxide, the heat produced during activity is almost inappreciable; and in other cases there may be a decrease or even complete cessation of all outward activities, *e. g.*, in structures that give an inhibitory response to stimulation; such an instance is seen in the swimming plates of ctenophores which stop movement instantly on slight mechanical stimulation. Facts like these again illustrate the extreme diversity which the entire sequence of events forming the response may show in different irritable tissues, in spite of the essential uniformity of the first stage of the process. This uniformity is the most remarkable feature of physiological stimulation. Nature has apparently found in the variations of permeability and of electrical polarization which external changes may cause in the protoplasmic surface-films the most effective and reliable means of which the internal processes of the protoplasmic system can be made to vary in response to variations in the environment; and in the course of evolution this mechanism has acquired a degree of perfection that still largely baffles physiological analysis.

THE PSYCHOLOGY OF RELAXATION

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THE gospel of relaxation has been eloquently preached to us by Professor James, Annie Payson Call and others. We have been told that we live under too much stress and tension, that we are too intense and carry too much expression in our faces, that we must relax, let go, unburden ourselves of many useless contractions.

There seems to be a good deal of truth in this. Some of us manage to escape neurasthenia, but few of us are free from fatigue, chronic or acute. We hear with amazement now and again some one say "I was never tired in my life." Surely under normal conditions we ought not to be so tired as we are, nor tired so often.

Under these circumstances a new interest has suddenly awakened in relaxation. The psychology of it is yet unwritten; the physiology of it is obscure; yet the need of it has become apparent. This need has lately been greatly emphasized by an outbreak of recreation crazes of which the dancing craze and the moving-picture craze are the most conspicuous. They have become so general and are so compelling that they even remind us of the epidemics of the middle ages. The almost obsessional character of these crazes may not be wholly explicable on psychological grounds, but it suggests the need of psychological inquiry into the nature of relaxation in itself and into the peculiar conditions of our times which issue, on the one hand, in the outburst of recreation crazes, and, on the other, in a rather wide-spread disposition to fatigue or even nervous disorders.

Meanwhile practical common sense, not waiting upon theory, has turned to discover means for relieving the excessive tension incident to our present habits of living. Some, as we have said, preach the gospel of relaxation, content to tell us that we are too intense. Others have established schools with practical and helpful rules and methods for relaxation and have brought comfort and relief to many. Again, a new and unique interest has suddenly arisen in *play*. Men and animals have always played—but now we have first become conscious of play and curious about it. We insist on play. If children do not play, we teach them to play.

Finally a score of movements, perhaps many score, have sprung into notice, whose purpose is to encourage or provide some form of relaxation. We recall the recreation movement; the physical-culture movement; the playground movement; the Boy Scouts; the Camp Fire girls; the ever increasing interest in athletics, not only in our colleges, but also in our high schools and grammar schools; the radical change in

Young Men's Christian Associations from devotional to hygienic and athletic religion; the renaissance of the gymnasium and the Olympic games; the increased interest in outdoor life of all kinds; the renewed devotion to outdoor games, like tennis, golf, baseball and football; the rapid extension of the play motive into almost every branch of education; the new vacation schools and school excursions; finally the supervised playgrounds, supervised folk dancing, supervised swimming, wading, tramping, gardening, singing and story telling. Even with very young children the Montessori system seeks to relieve the tension of the old task methods by making the child's activities natural and interesting as well as useful.

More than twenty-four hundred regularly supervised playgrounds and recreation centers were maintained last year in 342 cities in this country. A brand new profession has appeared, that of play leaders, employing 6,318 professional workers.

The legislatures of some states have passed laws requiring every city of a certain size to vote on the proposition of maintaining playgrounds. New York City expended more than $15,000,000 on playgrounds previous to 1908. The city paid $1,811,000 for one playground having about three acres. Chicago spent $11,000,000 on playgrounds and field houses in two years. Formerly the boy could play on the street, in the back alley, in the back yard; now the alley and back yard have disappeared, the street is crowded with automobiles and the few remaining open spaces are given over to the lawn mower and keep-off-the-grass signs, while more and more the school has encroached on the boy's precious period of growth, filling nine of the twelve months of the year and carrying the dreaded examination even into his evenings.

For reasons which will be shown presently boys *must* play. Take away the opportunity for legitimate play, and the play instinct, the instinct of rivalry, of adventure, of initiation, will manifest itself in antisocial ways. Hence the juvenile court and the reform school. "Better playgrounds without schools," says one writer, "than schools without playgrounds."

Our purpose, however, in this article is not to consider the practical and sociological aspects of play, important and interesting as they are, but rather its psychological aspects, the object being to determine if possible what play is and why it is necessary. We shall have in view not children's play merely, but play in its wider sense and especially the play and sport of adults.

Herbert Spencer was the first writer to propose a theory of play. Spencer's theory, which came perhaps from a suggestion of the poet Schiller, was that play is due to the overflow of energy, superabundant energy. It expends itself, therefore, in activities having no further end than the activities themselves, while work is due to the attainment of some end.

In so far as the Spencer theory emphasizes the spontaneous character of play as compared with work, it is illuminating. And if by superabounding energy Spencer means nothing more than a condition of vital health of which play is the spontaneous expression, his theory is helpful and true. But the impression that one gets from this theory is that quiescence is considered to be the natural condition of the child and that when energy superabounds then he plays. Thus far the theory needs a radical revision. Still more, the Spencer theory makes no attempt to explain the *forms* of children's play and of adults' sport, nor their historical significance.

The next theory of play was that of Karl Groos, developed in his two books "The Play of Animals" and "The Play of Man." It is called the "practise and preparation theory" and maintains that play is an *instinct* whose purpose, during the long period of immaturity, is to perfect through play the activities afterward required in serious life. For instance, the girl jumping rope doesn't know why she is doing it except that it is fun. But really it is an instinct whose purpose is to develop certain essential muscles.

This theory is less illuminating than that of Spencer. All the activities of children are in a sense a preparation for life, but the form taken by children's play is not the form of their future activities, except in a comparatively few of the imitative plays. As we shall see presently, the Groos theory does not apply to the characteristic and most deeply fascinating plays of childhood and youth. Without denying the truth that play is a preparation for life, a wholly different principle will be found to determine the form which the plays take. Groos has more recently supplemented his views by a "Katharsis" theory of play already suggested by American psychologists.

A third theory of play has connected the plays of children with the serious pursuits of primitive man. A mass of facts showing this connection has been collected by Stanley Hall and his school—facts which no future writer on the theory of play can ignore. The manner of this connection and the reason for it have not been clearly shown. Sometimes it has been included under the so-called law of recapitulation, a theory to which critical reference will be made below. For the moment, however, it will be sufficient to mention some instances of this striking resemblance between the habits of our human ancestors and the plays of children, calling attention to the fact that the resemblances extend not only to the plays of children, but also to the sports of men.

Haddon and Tylor have studied the history of the kite and the top and of marbles and have shown their very ancient character and their connection with early religious and divinatory rites. The same may be said of casting lots, throwing dice, games of forfeits and games with common playing cards. The mental habits of our ancestors, as we know,

survive in the counting out rhymes, in the charms and talismans and superstitions of children. One recalls the magic formula used by Tom Sawyer for driving away warts.

> You got to go by yourself in the middle of the woods where you know there is a spunkwater stump, and just as it's midnight you back up against the stump and jam your hand in and say:
>
> Barley corn, barley corn, injun meal shorts,
> Spunkwater, spunkwater, swaller these warts
>
> and then walk away quick eleven steps, with your eyes shut and then turn around three times and walk home without speaking to any one, because if you speak, the charm's busted.

The mental habits of the child seem like echoes from the remote past, recalling the life of the cave, the forest and the stream. The instinct exhibited in infancy, as well as in boyhood, to climb stairs, ladders, trees, lamp-posts, anything, reminds us of forest life; the hide-and-seek games which appeal so powerfully even to the youngest children recall the cave life of our ancestors, or at least some mode of existence in which concealment from enemies, whether human or animal, was the condition of survival; while the instinct of infants to gravitate toward the nearest pond or puddle, the wading, swimming, fishing, boating proclivities of every youngster, seem like a reminiscence of some time when our fathers lived near and by means of the water.

During a long period in the evolution of life among the higher animals and in the early history of man, the one all-important factor was *speed,* for upon it depended safety in flight from enemies and capture in pursuit. This ancient trait has persisted and survives to-day in a deep instinctive joy in speed, whether exhibited in running or coasting or skating or in the speed mania which lends such delight to motoring, flying, fast sailing and fast riding.

Again, the ancient life of pursuit and capture persists upon every playground in the familiar games of tag, blackman, pull-away, and a hundred others. Indeed, for the exhibition of this instinct, no organized game is necessary. Sudden playful pursuit and flight are seen wherever children are assembled. The ancient life of personal combat is mirrored in the plays of children in mimic fighting and wrestling. The passion of every boy for the bow and arrow, sling, sling-shot, gun or anything that will shoot, is merely the persistence of deep-rooted race habits, formed during ages of subsistence by these means.[1]

There was a time when man lived in close relation with and dependence upon wild and domestic animals. This period is reflected in many forms in the child's life, in his animal books, his animal toys, his teddy bears, in his numerous animal plays. The former dependence of man

[1] Comp. "The Psychology of Football," by present author, *Amer. Jour. Psych.,* Vol. XIV., pp. 104–117. A few paragraphs from this article have been repeated in the present one.

upon the horse is shown in the instinct of the child of to-day to play horse, to ride a rocking-horse or a stick or anything. The child's first musical instruments, the rattle, the drum and the horn, were the first musical instruments of primitive man. These illustrations could be multiplied indefinitely. They show the limitations of the Groos theory of play, for none of the plays of this class have much to do in preparing the child for the life of to-day, or in giving him special practise for his future work. We ourselves are so much slaves of the past in our habits of thought that we do not easily realize how far from the actual life of the present day is this play-life of the child. The real world of to-day is that of the laboratory, the school, the library, the bank, the office, the shop, the street, the factory, the farm and the railroad. Notwithstanding the child's strong imitative bent, his world, as shown in his tales, his dreams and the plays he loves best, is that of the forest, the stream, the camp, the cave, the hunting-ground and the battlefield.

Everything which has such a vital and absorbing interest for the boy has had at one time in our racial history an actual life and death interest for mankind. Take, for instance, the jackknife. How many knives has your boy had and lost and what rich joy there is in every new one! We see how the practise and preparation theory of play fails here. The knife has no significance in society now. It has degenerated to mere finger-nail purposes. But at one time it meant life in defence and food in offence. Your boy's supreme interest in the knife is a latent memory of those ancient days. Those who could use the knife and use it well, survived and transmitted this trait to their offspring. The same could be said of the sling, the bow and arrow, and of sports like boxing, fencing, fishing, etc.

Consider the fascination of fishing. This is not a practise and preparation for the real life of to-day, but a reverberation of racial activities. In a summer resort where the writer was a visitor the past summer, day after day the whole male population of the hotel resorted to the fishing grounds. They paid two dollars and a half a day for a guide, seven dollars a day for a motor-boat and a cent and a half apiece for worms. Surely a stranger uninitiated into our habits of thought would have been amazed to see these returning fishermen at night indifferently handing over their catch to the guide. It was the fishing they desired, not the fish, and yet great was their woe when one large fish was lost in the act of landing. It is estimated by the *New York Times* that on Sundays and holidays when the weather is fine, 25,000 people in New York City go fishing at a minimum cost of one dollar each, and of these no doubt more than 95 per cent. go for fun and not for the fish. At some stage in the history of human development fishing was without doubt a general means of subsistence. Those who could catch fish survived and handed down this instinct. Likewise the fascination of gathering wild

nuts and berries is out of all proportion to the value of them when gathered. But nuts and berries were once of vital concern to our fathers.

It is in baseball and football, however, that we best see the historical significance of play. The daily paper is a good index of popular interest. Here we shall often find perhaps seven, perhaps twenty columns devoted to baseball, while no other single subject whether in politics, art, literature or science, aspires to two columns. How shall we explain the absorbing interest in baseball and football as well as in horse-racing and prize-fighting?

In baseball we have a game combining three of the most deep-seated racial instincts, the instinct to throw, to run and to strike. During untold periods of the life history of our race, survival has come to him who could throw the straightest, run the swiftest and strike the hardest. To throw something at something is almost as natural for a boy as to breathe. Throwing, batting, running are no longer of any service in this age of mind, but they were the conditions of survival in the distant past. Baseball reinstates those ancient attitudes and brings a thrill of cherished memories. Any one who has ever held a bat in hand and assumed the expectant attitude of the batter knows the peculiar thrill which is explained only by recalling that his distant ancestors in just that attitude beat down with a real club many an opposing foe, whether man or beast, and those who held clubs in this position and struck hard and quickly survived and transmitted this instinct. Dr. Gulick says:

> Baseball is a complex of elements all of which date back certainly to our prehuman ancestors. The ability to throw a stone with accuracy and speed was at one time a basal factor in the struggle for survival. The early man who could seize a bough of a tree and strike with accuracy and great power was better fitted to survive in the brutal struggles of those early days than the man not so endowed. He could defend his family better, he was better fitted for killing game, he was better fitted for overcoming his enemies. The ability to run and dodge with speed and endurance was also a basal factor.[1]

The instinct to throw, as the same author shows, belongs to boys only, scarcely appearing in the case of girls. The awkward throw of girls, like the left arm throw of boys, is well-known. The plays of girls reveal their own set of instincts recalling the habits of primitive woman. "We are the descendants of those men who could throw and those women who loved children."

Football excites still greater enthusiasm than baseball because it reinstates still more primitive forms of activity, for instance the face to face opposition of two hostile forces, the rude physical shock of the heavy opposing teams, the scrimmage-like, mêlée character of the collision, the tackling and dodging and the lively chases for goal, as for cover. The spectators at a great football game go wild and behave like children,

[1] Interest in Relation to Muscular Exercise," by Luther Gulick, M.D., *American Phys. Ed. Rev.*, Vol. VII., 2.

shouting, gesticulating and throwing their hats into the air, because before them is enacted again the ancient, familiar scene.

Success in modern life does not depend upon swiftness of foot or swiftness of horse, yet our sports take the form of foot races and horse races. There was a time when swiftness of foot and swiftness of horse were vital. So in our sports these old scenes are reenacted. Few of us can read a vivid account of a horse race or chariot race without profound emotional disturbance, out of all proportion to the actual significance of these things in the life of to-day. In fact they have no significance whatever now. They belong to the past. So it is of hurdle jumping, hammer throwing, shot putting, trapeze performing, and all the events of the circus ring, the athletic track, the stadium or arena. They reenact ancient scenes and old forms of racial activity. The boy swinging on a trapeze or hanging by his toes from the limb of a tree is not practising the things he will have to do in later life, and this activity is of no value to him as "a practise and preparation for life," except so far as any physical activity contributes to his bodily development. A boy must be active, and activity is essential to his development, but the form of his activity is to a great extent determined anthropologically and his delight in it is directly proportional not to its future usefulness, but to its historic truthfulness.

The sports of the ancient Romans illustrate, just as ours do, this character of play. There is authority for the statement that 385,000 spectators were present in the Circus Maximus at one time.[3] The spectacle that fascinated them was the age-old spectacle of man fighting with man in deadly combat, and man with beast, and beast with beast.

Such, then, are some of the facts illustrating the curious resemblance between the habits and pursuits of early man, on the one hand, and the plays of children and the sports of men, on the other. Is it possible to explain this resemblance and arrive at a satisfactory theory of play? An attempt has been made to show a kind of parallelism between the mental development of the child and the historical development of man and to include this parallelism under the so-called biological law of recapitulation. But this theory, sometimes called the recapitulation theory, encounters no less difficulties than the Spencer theory or the Groos theory. Even if the law of recapitulation were generally accepted by biologists, it would not explain the plays of children to refer them to it. There would still be only a resemblance—or at the most a parallelism. But more serious difficulties arise. This theory makes no attempt to explain the sports of adults and it is becoming increasingly evident that the plays of children and of men are to be explained on the same principle.

[3] Some manuscripts of the Notitia give the number as 485,000. Some modern critics believe that the actual seating capacity of the Circus was only about 200,000 at its greatest enlargement. Great crowds, however, witnessed the events from the surrounding hills and houses.

If it could be shown that the child passes through the various stages of development that the race passed through, this would throw no light on the sports of men.

Nor again does this theory explain the delight which children take in their play nor does it make clear the distinction between work and play. Why does a boy become so quickly fatigued hoeing in the garden or raking leaves when his physical endurance is beyond belief when hunting, fishing or playing football? It is commonly assumed that in the former case the fatigue is fictitious, but this is not the case, as the results of forced child labor always show.

Finally this theory admits of no clear educational application. All the writers of this school assume that since the child's plays tend progressively to take the forms of the serious pursuits of his ancestors, therefore these tendencies should be encouraged. Every child, they say, must live out and live through these stages in order that he may enter into the next stage sound of body and mind. This may be true, but no satisfactory reason for it has been given. Why rather should not these survivals of savagery be discouraged and the boy's plays be modeled after his future manly duties?

Failing thus to find the recapitulation theory of play any more satisfactory than the other theories, but recognizing the full value of the facts from which it sprang, let us see whether these facts are not susceptible of a somewhat different interpretation.

It is evident that progress in civilization has depended upon the development of certain peculiar forms of mental activity which were relatively undeveloped in primitive man. If it be true that these forms of mental activity are relatively undeveloped in the child and when developed in the adult are most susceptible to fatigue, we have at once the key to the whole problem of sport and play, explaining why the plays of children and the sports of men take the form of primitive human activities.

It is not necessary for our present purpose to attempt any exact description of those forms of mental activity which are newest in human evolution. Commonly they are exhibited as a constantly increasing power of inhibition and a constantly increasing capacity for sustained attention, and they depend no doubt upon that growing complexity of brain structure which makes possible and easy new forms of association. The individual becomes able therefore to hold steadily in view the image of a desired end, to inhibit the old and habitual responses which are no longer appropriate to that end, to analyze a given situation in thought so that the response may be to certain elements in the situation rather than to the situation as a whole, and thus to meet a given situation with a new response.

Even in the lower forms of animal life this tendency appears as the

persistent striving of the organism toward an end, that end being usually some changed relation which shall subserve the life purposes of the individual. This striving has for its subjective correlate a state which we may characterize as tension, strain, stress or effort. It is this aspect of human behavior that constitutes work and distinguishes it from play. It is the power to hold oneself to a given task for the sake of a given end, to carry on an occupation even though it may have ceased to be interesting for the sake of some end to be gained other than the activity itself. This is work and it involves stress, strain, tension, effort, endeavor, concentration, application and inhibition, and is unconditionally the ground of progress. It is precisely the lack of this capacity for sustained and persevering effort that characterizes all uncivilized races.

Play is just the opposite and includes all activities in which the stress and strain are absent. Play is self-developing and supplies its own incentive. It is spontaneous and pleasant because of the sense of ease which accompanies it. Clearly play in this sense is something broader and more inclusive than those activities which we usually embrace under the term. It includes not merely children's plays and grown-ups' sports, not only hunting, fishing, boating, yachting, motoring, flying and all kinds of outing, not merely games and races and spectacles and tournaments and fairs and expositions, but also the theater and the opera, the enjoyment of music and painting and poetry, our daily paper and our magazines and our novels and our romances, and for that matter, many forms of so-called work in which the interest is self-developing, such, for instance, as gardening for pleasure. Relaxation or recreation would be perhaps more fitting terms to designate this large class of human activities.

All the evidence that we have points to the validity of the law that those peculiar forms of mental activity which have developed late in the evolution of man are most affected by fatigue—a law fully sustained by the study of psychasthenics and their incapacity for higher mental operations, as well as by the observation of people normally fatigued, while it is known that the disintegration of the nervous system in disease follows the reverse order of its development.

The application to the explanation of adult sport is evident. Those forms of mental activity which are developed late in the history of the race, and late in the life of the child, that tense and strenuous activity upon which modern progress depends, the power to hold ourselves by sustained attention and sustained effort down to hard and uninteresting tasks for the sake of some ultimate end, the concentration of the mental forces upon problems of science, philosophy and invention, and the inhibition of old and undesirable responses—all these bring quick and extreme fatigue and demand rest for the corresponding

parts or centers of the brain. In sleep these higher mental processes enjoy almost complete suspension. But the exercise of these powers during the long hours of our waking day would result in speedy collapse. It is clear therefore that our daily activity must be made up quite largely of responses of the simpler type, which shall give exercise to our muscles and sense organs and invoke older and more elementary forms of psychosis, and at the same time allow the higher ones to rest. Such is relaxation in all its forms and of such consists almost wholly the life of the child. For the brain centers associated with the above-mentioned forms of mental activity are undeveloped in the child as they are in primitive man, so that we may say with considerable truth not that the child *ought not* to work, but that he *can not* work.

So we understand why adult sport resembles the activities of primitive man. The older, the more basal, the more primitive, so to speak, the brain centers used in our hours of relaxation, the more complete our rest and enjoyment. Just in proportion as the sport is primitive, so much greater is the sweet peace which it seems to bring to the troubled soul, simply because it involves more primitive brain tracts and affords greater release from the strenuous life. So while we find one hundred and fifty spectators at an inter-collegiate debate, we find a thousand at an automobile race, five thousand at a horse-race, twenty thousand at a great baseball game, fifty thousand at a great football game and 385,000 at a gladiatorial show. The nervous tracts which function in such activities as hunting and fishing and swimming and boating and camping and in football and baseball and golf and polo, in horse-racing and bull-fighting, are deep worn, pervious and easy. During countless centuries the nerve currents have flowed through these channels. Witnessing these rude contests, pictures of former ages, or taking part in these deep-seated, instinctive actions brings sweet rest and refreshment. "The racially old is seized by the individual with ease and joy."

The game of golf has a peculiar restorative power surpassing all medical or other therapeutic arts. We may be physically and mentally weary from a morning's work. Despite the strenuous physical exertion of an afternoon at golf, our fatigue is lessened, not increased. Fresh air does not explain it. It is a return to the primitive outdoor life. We stride over hill and through ravine; we stumble into ditches; we carry a club and strike viciously at the ball; we follow the ball with the eye and search for it in the grass as our forefathers searched for their arrows and missiles; we use our legs and our arms; we let the nerve currents course through the more ancient channels; we revel unconsciously in latent memories and old race habits and come back to our work rested, renewed and refreshed.

But you may say golf and bowling and baseball and prize-fight-

ing require skill and close attention and tax mind as well as muscle. But this is not the point. Our primitive ancestors had skill. To see quickly and correlate nicely eye and hand or eye and foot was an early acquisition. It is not this that fatigues us in modern life. It is the everlasting, high-pressure grind. It is the holding ourselves down to hard working and hard thinking and long-sustained tasks. It is analysis, concentration, effort, dead lift of mind, the kind of psychosis that digs Panama canals, perfects automobiles and airships, discovers new laws of mind and matter in the laboratory, thinks out new fields for the investment of capital, scrutinizes countless court records for precedents in law which may clear our clients, holds the ship's captain on the bridge in times of peril, keeps the soldier at his post and the clerk at his desk through the long hours and the weary days. As the strenuous life increases in city and country, there is an increased demand for relaxation, whether in the form of baseball or football, horse-racing or gambling, or in the form of the automobile craze or the auction-bridge craze or the moving-picture craze or the tango-dancing craze. These are all methods of escape from the clutch of the modern strenuous life, exhibited in all countries, but most noticeably in America, for whatever it is that is driving the human race forward in the path of progress so rapidly and relentlessly, seems to have gripped the Anglo-Saxon people particularly hard.

Even these many forms of relaxation are not sufficient to relieve the overwrought brain centers, and so in ever-increasing amounts we have recourse to artificial means of relaxation through narcotics, such as alcohol, tobacco and other drugs. Alcohol by its slight paralysis of the higher and later developed brain centers, accomplishes artificially what is effected naturally by play and sport, that is, it liberates the older, freer life of the emotions and the more primitive impulses.

Thus from our new point of view the difficulties in regard to children's play disappear. The reason why children play and why their plays take reversionary forms is now evident. The higher brain centers, those making work possible, are not developed. If a child does *anything,* he must play, *i. e.,* his activity must take the form prescribed by the brain centers already developed, and these are the old racial tracts. He is equipped with a nervous mechanism adequate for old racial activities and for the most part with these only. The little girl hugging and nursing her doll is not the victim of an instinct whose purpose is to prepare her for later maternal duties. She is simply doing what her mother and her grandmothers have done since the foundation of the world. If they had not done so, she would never have been born.

The child does not play because of surplus energy, for under normal conditions *all* his energy is expended in play; the child is a playing animal. Nor does he play because of an instinctive need of practise and

preparation for life's serious duties, for the form of the latter is constantly changing while the plays of children remain much the same from year to year and century to century. Nor finally does he play because it is necessary for his complete growth that he should pass through the several stages of racial history. He plays because he is a child and to the child's natural and active life we give the name play to distinguish it from the life of conscious self-direction, of strain and effort and inhibition which evolution has imposed upon the adult human being.

When we say that all of the child's activity takes the form of play, the statement should be regarded as a general one and as such it is true. As the term play is actually used there are certain minor classes of responses which are not included. The child's instinctive shrinking from a large furry animal is as much a part of his original nature as his tendency to run and jump and climb and wade. His responses in the taking of food, likewise, and in protecting himself by crying are original inherited responses. But to crying and sucking and shrinking from objects of fear we do not give the name play, because, being of the immediate life-serving kind, they bear a closer resemblance to those responses to which in later life we give the name work, and we reserve the term play for that larger and characteristic class of activities which are distinguished from the conscious self-directive life of the man. The play reactions of children therefore belong to their original nature. They are instinctive. Social heredity may account for the forms of organization of many of the plays of children as well as the *sham* character which they assume when compared with their originally serious form, but the *elements* of the great mass of the plays which are dearest to the hearts of children are truly instinctive.[4]

Possibly the objection may be made that in this account of children's play, our attention has been directed too much to the plays of boys and that the plays of girls have been disregarded. An important distinction arises here to which in this present writing only passing reference can be made. The life of stress and effort and self-direction of which play is the antithesis is essentially masculine. Man represents the centrifugal motive; he stands for movement, change, variety, adaptation; for activity, tension and effort. Woman represents the centripetal motive; she stands for passivity, permanence, stability, repose, relaxation, rest. She has greater measure and harmony. She has therefore less need of the release afforded by primitive forms of activity. Girls, of course, play and their plays follow the same laws as those of boys, but yet in less marked degree, while adult sports are for the most part masculine sports.

Just at present what we call civilization is tending in the direction of the masculine motive—to variation, adaptation, change—to effort,

[4] Compare James's "Psychology," Vol. II., p. 429, *note*.

stress and work. That it is producing anything remarkable, except in invention and the mechanic arts, is doubtful. The really great things of the world have been produced not with great effort, but with great ease. The magnificent productions of the age of Pericles in architecture, sculpture, painting and literature seem to have been more like the overflowing of a full vessel than like the laborious achievements of hard work. But the present age is the age of great effort, the age of work, and hence our growing demand for more relaxation and rest.

The educational application of this theory of play presents less difficulties than the older theories. It is not necessary that the child should live through and live out any series of savage stages. It is merely necessary that he should be kept active with the mental and physical equipment that he has, that work should not be too early imposed upon him and that his plays should be so organized and supervised that, while retaining the elementary form of his instinctive responses, they may be physically, morally and socially harmless. For instance, a boy, if he is a boy, must throw. It is just a question of whether he shall throw stones at a cat, at a street car, at little children or whether he shall throw a curved ball to the catcher. The latter is harmless, the former dangerous. Again, a boy's instinct of rivalry is very strong. He must do something daring, get ahead of some one, as those of his ancestors who survived did before him. If a proper playground is provided, all these things may be done without injury to society. Otherwise his instinct is expended in an effort "to steal on Casey's beat and get away with it." Again, at a certain age the dancing instinct is developed and the children must now be taught the graceful and healthful folk dances.

In our modern cities supervised play has become necessary for social order, for the reason that the old conditions of spontaneous, healthful play have been taken away. Says Luther Burbank quoted by Geo. E. Johnson:

> Every child should have mud-pies, grasshoppers, water-bugs, tadpoles, frogs, mud turtles, elderberries, wild strawberries, acorns, chestnuts, trees to climb, brooks to wade in, water-lilies, woodchucks, bats, bees, butterflies, various animals to pet, hay fields, pine cones, rocks to roll, sand, snakes, huckleberries and hornets; and any child who has been deprived of these has been deprived of the best part of his education.

As regards adults, the social applications of the theory are equally obvious. There must be large periods of relaxation from the high tension life of to-day. If they are not provided in the form of healthful and harmless sports, there will be irritability, abnormal fatigue and antisocial outbreaks. There will be tango-dancing crazes and auction-bridge crazes and there will be ever-increasing resort to the temporary harmonizing effect of alcohol, tobacco and coffee.

Even in the life of the family the harmonizing influence of games

is seen. The friction sometimes exhibited among its members, in some cases taking the extreme form of nagging, wrangling and quarreling, is no doubt due in large part to the fatigue of the higher brain centers. In such cases it will often be found that participation in some simple game, particularly an outdoor game, such as golf, tennis or even quoits, will completely relieve the situation, bringing sympathy, harmony and peace. In society, the larger family, the same effect must follow upon the larger participation in healthful sports. It is sometimes a matter of surprise to us in periods of national prosperity when wages are good and work obtainable, that unrest increases, together with crime and insanity. It may be because the high tension with its consequent fatigue is not relieved. What is needed is less work and worry and more healthful relaxation. Worry is a good example of the high-tension life that is a part of our civilization. Worry is only an excessive form of prevision. It is well enough for preachers to tell us not to worry, but worry is precisely that form of behavior upon which civilization depends, namely, solicitude and care for the future. As a nation we are just beginning to worry, for instance, about the depletion of our forests and soil, and it is well that we are doing so. But sometimes we become excessively solicitous about the future, whether it be about the rent or the winter's supply of coal or our future health or the health and morality of our children, and this is what is usually spoken of as worry. It is very wearing, for the reason that it brings constant strain upon delicate and recently developed brain centers and makes relaxation imperative.

If we have correctly described the theory of play and the psychology of relaxation and their relations to the conditions of our modern life, it will be evident at once that the need will not be supplied merely by providing more playgrounds for children and more holidays and sports for grown-ups, vital as these are. The difficulty goes deeper and calls for emphasis of still other forms of relaxation than play and sport. There are many of these, such, for instance, as music, which is one of the best, and rhythmic dancing, which, being very ancient racially, is a form of relaxation of unsurpassed value. An ever-ready and convenient form of relaxation is the modern novel, in which the attention is sustained objectively as in the chase or the drama, but its value as relaxation is greatly less than in the old and social story telling. Society in all its forms is a healthful means of relaxation. All valuable games and sports are social and the mere mingling with our fellows lowers the mental stress and tension. Primitive man was wholly social and survived only in cooperative groups. The reversionary character of crowd behavior has been made well known to us.

Religion may be mentioned finally as a mode of relaxation of the highest value. Religion is a letting go the stress and tension of the in-

dividual and resigning oneself to an outside power, whether that power be God or the church. The function of religion in this aspect is that of a sustainer, and religion loses its usefulness wholly if the individual, as is often the case, feels it his duty to sustain his religion. His religion must sustain him. Clubs, societies, fraternities of all kinds, exercise a similar function. The great charm of all fraternal societies is that they relieve the stress, the burden, the tension of the individual and shift the responsibility upon the society as a whole. The society is back of him, to some extent will do his thinking for him, decide moral questions for him, relieve his worry.

Just as man has physically lifted himself from the earth, overcoming gravity, so mentally he has raised himself above the other animals by the fatiguing exertion of his higher mental powers. The first animals were marine animals. They floated in or upon the water without effort. Then came creeping land animals prone upon the ground but not so completely supported as in the water. Gradually the animal lifted himself upon four legs and at last, by infinite labor, erect upon two, and the tension is correspondingly great. The horse rests very comfortably upon his four legs if allowed to stand and needs to lie down scarcely an hour in the twenty-four. Man sustains himself with constant effort in an erect position and must sit much of the time on a chair and at night reverts to the original position of the worm, prone upon the bed. This illustrates the whole theory of relaxation. It is always some form of reversion to primitive attitudes or primitive psychoses and it brings rest and peace and harmony.

The rhythm of moral and social progress probably follows the same law. Periods of rapid progress are followed by periods of rest and relaxation. From time to time we are shocked by waves of vice and epidemics of immorality. We hear suddenly of conditions of astonishing laxity of morals in the small towns of our western states which are supposed to be models of propriety and we say that the world is going to the bad. But our judgment is too hasty. These things are stages really in progress. What we witness is a kind of moral relaxation, a relapse to more primitive conditions, as a result probably of progress that is too rapid, of tension too great. Something like moral fatigue takes place and a reaction follows.

Just at present we are hearing it said that our country has gone "amusement mad." Well, our manner of life has been very strenuous. The tension has been high. Something was bound to happen. Other forms of relaxation have failed us just when we needed them most—particularly art and religion. We are told that the art of ancient Greece was the product of the Greek genius. Perhaps it was the cause of it. Both art and religion entered intimately into the daily life of the Greeks. They have departed from ours.

THE NEED FOR A SALARIED MEDICAL PROFESSION

By Professor PAUL L. VOGT
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THE state, in the interest of its own preservation and progress, has assumed control of certain activities closely affecting the life of every citizen. Among these are the care of the public roads, the distribution of the mails and the education of the youth. Still other activities now in private control should be supported by the state for the benefit of the whole people. One of the most important of these and the one perhaps receiving most public attention at the present time is the care of the health of the people, a function now delegated largely to physicians, men who receive their reward for community service in the form of fees from private individuals.

Attention to the public health presents two aspects, the one preventive, intended to preserve health by removing the causes of disease; the other curative, and intended to restore to health those who have fallen ill. The medical profession, through a large part of its history, has been almost exclusively concerned with problems of curing disease. The physician has had no direct financial interest in warding off disease from those who were well, but has dealt only with individuals who were ill. Until recently nothing was done to remove the cause of disease, the attention of the physicians being directed toward the problem of finding means of curing or relieving the pain of the one who had already contracted disease.

This was the logical course for physicians to pursue because it was from the sick individual and not from a well public that he received his pay. Under the present system the physician is prosperous in inverse ratio to the health of the community. The doctor is busiest during those seasons when illness prevails most. Were there no disease there would be no need of physicians. This would be an ideal condition for which the people would be glad, not because of hatred of physicians, but because of love for their own welfare. Since the physician to-day receives his reward from the curative side of medical practise he is not professionally interested in the prevention of disease. The public need is for a medical fraternity paid by the public whose interests will be as much in the prevention of disease as in the cure of it. Were physicians paid by the state, they would not fear the loss of income through working for the interests of the well, while at the same time attending to the ill, because the lessening of illness would not necessarily interfere with

their incomes. Further, the greater their success in the prevention of disease the less the labor that would be required in the cure of it.

Under the present system much dissatisfaction exists over the charges made by physicians. The poor patient will get together $200 or $300 for an operation or will be treated by novices free of charge, while the rich man will pay $1,000 for the same service. The physician is bound by the ethics of his profession to heed the call of every individual without any preliminary inquiries as to ability to pay, and must give both prescriptions and medicine to many without hope of reward. He must depend for his livelihood upon the honesty and liberality of those who are able to pay for his services. It also places the burden of caring for the sick poor upon the sick well-to-do, because the physician must make his charges according to the net income desired. The system further tends to develop a class in the community that is looked upon as a pauper group requiring care according to special methods. Out of this condition has risen the system of free dispensaries to which physicians volunteer their services, and to which the poor may go for treatment. The physician prefers to volunteer his services to an institution of this kind rather than have the poor come to his office to interfere with his private practise. Their presence in the office is desired about as much as is the presence of the colored person in the office among white patients. The poor are made to feel the disgrace of their poverty and the well-to-do who frequent the dispensaries are induced to falsify as to their real ability to pay.

The present system is unfair to both the physician and the public. The young practitioner, eager to gain experience, is perhaps rewarded for the voluntary service rendered, but the experienced physician who must devote a certain portion of his time to unremunerative practise is unjustly treated. In certain cases he may derive benefit from the voluntary service in that it may bring him into touch with diseases not usually met with in regular practise. But the general dissatisfaction with the growth of free dispensaries, hospitals, etc., is proof that the medical profession is opposed to both an excessive volunteer service and to a diminished practise. On the other hand, it is unfair to the public because it places upon the poor the stigma of asking for assistance for relief from illness for which he is perhaps not responsible. Prevailing materialistic standards permit the erection of buildings that pure air and bright sunlight never penetrate and that in time become veritable breeding grounds of disease. The poor man, because he is too poor to afford anything better, is forced to live in these dens with every chance that both he and his family will contract serious illness. He goes to the free dispensary and is liable to have his home pried into by some charity visitor or to become known as the recipient of alms. The individual receives the burden that a neglectful society has placed upon him and is

stigmatized because he must shift it—too heavy to bear—to the shoulders of other individuals who operate a free dispensary.

The present system prevents adequate and timely aid to those who need it. Many people, even within reach of dispensaries, dread the thought of patronizing them and often waste their earnings in buying nostrums from the neighboring drug store because they are cheap and because they seem to fit their case. Ofttimes they injure themselves more than they help. The pauper, who has lost all sense of deference to public opinion, goes at once to the dispensary and is adequately treated. But the vast multitude, too proud to patronize a dispensary and too poor to patronize a physician, run continual risk of neglecting serious illness.

The preservation of the public health is a matter of too great importance to be entrusted to the care of the person who is ill and who feels too poor to go to the doctor. The sick person becomes a non-producer and a care to his family and friends. If the father becomes ill the family becomes a public charge. If the children contract disease they suffer and die because the poverty of the parent prevents proper medical attendance. The masses of the people are too poor to avoid the risk of letting disease run into the danger period. Conditions demand nothing less than the removal of the stigma attached to dispensary patronage so that any person, be he rich or poor, can go to be treated. Medical attendance should be as free as the public schools. The healthy and well-developed body is as important as the healthy and well-developed mind. The two go together and the one can not be perfect without the other.

If, instead of lessening the amount of free medical attendance it were made universal the present fee system would be limited to the very wealthy and the physician for the common citizen would be placed on a salary basis. This would entail a large increase in public expenditures. Such an increase, however, would be a blessing in disguise in that it would fix public attention on the prevention of disease, thus lessening the amount of suffering in the community by eliminating the causes of it. It would open the way for a great number of people who are now deprived of proper medical oversight to consult a physician before real danger is present. It would eliminate the volunteer work and the charging of the rich to make possible the medical attendance of the poor. The emphasis in medical practise would be shifted from the curing to the prevention of disease. The physicians paid for by the state would become agents in removing the causes of disease. Instead of devoting exclusive attention to the cure of the consumptive or the one afflicted with other ills, contagious or otherwise, they would be concerned with the removal of the causes of the spread of the disease. The public physician would also become the agent for the dissemination of popular information on subjects of hygienic interest. In other words,

it would bring the medical profession into line with the highest interests of the social group which they serve and would make the physician in relation to the preservation of public health what he now is in relation to the cure of illness, a leader in the fight for the extermination of disease.

The transition from a fee to a salary system of payment for medical service would not necessarily eliminate private practise. Those wishing the services of a private physician could secure the same at a rate based on value of services actually rendered. The existence of public schools has not eliminated private schools from the educational system. Neither has the public school system resulted in less consecrated service to the public welfare than was rendered by the private school. Neither should a salaried medical profession be less consecrated to its work than one rewarded by fees.

The transition from a private to a public medical practise is gradually coming. The appearance and persistence of free dispensaries and hospitals is not the least evidence of the change. The establishment of departments of health in city and state, the magnificent work of the medical service of the United States government; the system of engaging a company physician adopted by many of the large corporations; the movement toward medical inspection of school children with its accompanying treatment at public charge of children unable to pay for treatment; and the movement toward the public treatment of certain types of disease, such as tuberculosis, all indicate that a new order is coming wherein prevention of disease by trained and paid public servants will be considered as important a matter as the cure of disease already contracted. The economic interests of the medical profession will be brought into line with those of the general public and this is the end which should be sought.

IS THE MONTESSORI METHOD A FAD?

By FRANK PIERREPONT GRAVES

PROFESSOR OF THE HISTORY OF EDUCATION IN THE UNIVERSITY OF PENNSYLVANIA

AFTER all the popular excitement, spectacular magazine articles, and more or less interesting books on the subject, the busy man—even the educator—is still asking: "What is the Montessori Method?" Is it a wonderful discovery of educational principles, an ingenious invention of material and devices, or merely a new fad that has been exalted by manufacturers of educational apparatus and enterprising journalists into a profitable cult and propaganda? Will the inventor of the "didactic apparatus" be eventually enshrined a little above Pestalozzi and Froebel, Mann and Barnard, in the educational pantheon, or will she be relegated to the limbo of the exponents of tiddledy-winks and ping-pong, of Belgian hares and Teddy bears? While "neither a prophet nor the son of a prophet," it is in the hope of answering such questions and of satisfying such a mild curiosity, that this sketch is added to the pyramid of Montessorian literature.

In the first place, it should be noted that Montessori is on the right track in seeking a scientific basis for her educational structure. Despite the close resemblance of the "didactic apparatus" to the "gift of Froebel," it does not find its justification in German idealism Happily the practise of Montessori, which is so similar to that of the kindergarten, is not handicapped with the necessity of awakening the innate concept of "unity" by "adumbration" in the unsuspecting child through his activities with an ordinary ball. The symbolism, mysticism and obscurantism of the literal Froebelians are replaced by a scientific basis of modern biology, physiology and psychology. Some of Montessori's biological statements have been shown by scientists and physicians to be inadequate, incorrect, or out of date, but, with the rapid expansion of modern science, it is almost inevitable that an educationalist should occasionally reveal a weakness when he builds upon a biological foundation. The scientific attitude of Montessori is an outgrowth of her training and experience. She was the first woman to receive the doctorate in medicine from the University of Rome, and she has followed up this medical education with careful study and researches in psychiatry, experimental psychology, anthropology and pedagogy. And it was her success in supervising the instruction of defective children that led to the experiments that have so stirred the educational world. Her procedure in teaching normal children has funda-

mentally adhered to the "physiological" method of Seguin, the first great trainer of defectives, and she frankly acknowledges this indebtedness. The scientific foundation of her practise is further shown in the conduct of her schools. Careful records are kept concerning the heredity, parental occupation, feeding and infantile sicknesses of the Montessori pupils, and anthropometric measurements are taken at regular intervals. Moreover, an expert inspection is periodically made of the sanitation and economic conditions in the home of each child.

The Montessori spirit is again revealed in her attitude of allowing the pupil as complete freedom as possible and of holding that the chief function of the teacher should be to study the activities of the child. "The transformation of the school," says she, "must be contemporaneous with the preparation of the teacher. For if we make of the teacher an observer, familiar with the experimental methods, then we must make it possible for her to observe and experiment in the school. The fundamental attitude of scientific pedagogy must be, indeed, the *liberty of the pupil.*" In practise, Montessori carries out this fundamental belief more fully than most Froebelians, who also profess it. Instead of holding the children to a fixed and complete order of exercises imposed by the teacher, she maintains that all education worth having is "autoeducation." The children should select their own occupations and solve their own difficulties, and should be allowed to develop themselves both mentally and morally. Only when their activities interfere with the general interest or are useless or dangerous, must they be suppressed. However, while in this latitude toward individual expression Montessori carries out the "following, not prescriptive" education of Froebel more logically than that reformer himself, she does not develop participation in group activities to the same extent as he. Nor is the material used as rich and varied. There is little opportunity afforded for the Froebelian construction and invention, and the development of imagination is ruthlessly nipped in the bud. The interesting plays, songs and stories of the kindergarten find little parallel in the Montessori practise, although at present the founder of the system seems to be expanding these elements. The conception of "autoeducation" is admirable, but it is difficult to see how genuine activities are to be carried on, except within a very narrow scope, unless the material of the Montessorian schools be expanded considerably beyond the confines of the "didactic apparatus."

The most discussed features of the Montessori method fall naturally into three groups. It should be noticed that none of these exercises are absolutely original, but they are sufficiently peculiar to demand consideration in any description of Montessorianism. They are connected with (1) activities of practical life, (2) sense training and (3) the formal studies of the elementary curriculum. (1) When the child first enters

the school, even while he is beginning to find himself, he may take part in the activities of practical life. Besides practise in ordinary courtesy, cleaning the room, setting the table, serving a meal, and washing the dishes, the children learn how to button, lace, hook and clasp various articles of dress by means of a unique apparatus. To the opposite sides of light embroidery frames are attached strips of dress material, linen and leather, which are fastened together at the center. Through constant practise with these materials the child learns to dress himself and trains a variety of useful muscular coordinations. Similar exercises in the activities of ordinary life have for some time been a part of the practise of progressive kindergartens and other modern schools. It may well be that Montessori has suggested several new features in this direction, but we must not suppose that the idea is absolutely novel or that we can follow these devices literally without further consideration. There is always danger that the Montessorians, like the Froebelians, may forget that "the letter killeth, but the spirit maketh alive." His more conservative disciples, in their efforts to preserve all the prescriptions of the master, have often forgotten that Froebel's system was adapted to conditions three quarters of a century ago in the simple and peculiar environment of a small German village. Let the Montessorians take warning and elaborate their principles in a practise that will be applicable to the complexities and independence characteristic of the twentieth century in the United States.

(2) The sense training is the feature most stressed by Montessori herself. Even her remarkable achievements in teaching writing seem to have been forced upon her by the parents of her pupils, who insisted upon the acquisition of something useful by their children. Like Myra Kelley's boy of the Ghetto, they believed the children had not time "to fool with their arms and legs." But with Montessori the sense training is the very essence of her work. She sees in it the biologico-psychological foundation of her system. If this position be maintained, Montessori would logically be regarded as a Simon-pure disciple of Seguin. Her apparatus is strikingly like that used for half a century in American schools for defectives. Even the "three periods" of Seguin find a place throughout her method. For example, she proceeds with the pupil in her training for touch:

(*a*) "Smooth, rough; smooth, rough."
(*b*) "What is this?" "Smooth." "What is this?" "Rough."
(*c*) "Give me the smooth." "Give me the rough."

Moreover, while such sense exercises are doubtlessly of great value in training defective children, the assumption of their usefulness in the education of normal children seems to be based upon a psychology, which, to say the least, has been rudely shaken. Apparently in this

Montessori adheres to the theory of "formal discipline." The exercises are intended to train *general* powers and discriminations. She maintains that: "the aim is not that the child shall know colors, forms and the different qualities of objects, but that he refine his senses through an exercise of attention, of comparison, of judgment; the exercises are true intellectual exercises." And this underlying theory is clearly to be perceived in the nature of the apparatus itself. The primal sense of touch is first exercised, as we have implied above, by passing the finger-tips of the children over various materials and pronouncing their nature as "rough" or "smooth"; and then by having the children name and select them by this description. Similarly, other general senses are developed —the "thermic," the "baric," the "stereognostic," the "visual," including color and form, and the "auditory."

(3) But, despite her own belief and wish, the feature of the Montessori system that has attracted most attention is its apparent success with the formal studies, especially in the facility and enthusiasm with which the children learn to write and in the beauty of their writing. The inventor of the method, of course, declares that this spectacular performance is of little account, save as a single link in the chain of sense development. All the tactile, dimensional, form and visual training, she holds, leads naturally to the writing coordinations. She has, however, made a most careful independent analysis of the writing process into its elements, and has invented three exercises by which the approach to the spontaneous development of the graphic language is directly accomplished. First, the "muscular mechanism to hold and use the instrument in writing" is developed by the child's filling in the outlines of a geometrical form that he has traced upon paper. During this period the child is also engaged in "exercises tending to establish the visual, muscular, and auditory image of the alphabetical signs" by means of sandpaper letters mounted on cardboard. The teacher shows the child how to follow the contour of a letter with his finger as if writing it and at the same time pronounce the sound (not the name) of the letter distinctly. Lastly, he is exercised in the composition of words by selecting unmounted cardboard letters from compartments in a set of boxes resembling a compositor's type-cases. "Now the child, it is true, *has never written,* but he has mastered all the acts necessary to writing." This is the secret of the much lauded "explosion into writing." The art is learned so unconsciously that the children begin it almost spontaneously and are writing before they realize it. This seems to be one decided achievement of Montessorianism, and if it can be applied to other languages not as phonetic as the Italian, it may be regarded as a permanent contribution to special method.

The Montessori methods in the other formal subjects—reading and arithmetic—are not as striking. Reading is generally acquired after

writing through the names of familiar objects written on the blackboard or upon cards. The word is shown the child, and if he interprets the sounds correctly, the teacher has him repeat them more and more rapidly until the word as an entity, and not as a succession of sounds, dawns on his intelligence. After single words can be read with some facility, progress is made to short phrases and sentences. But there is nothing very novel about this method of securing interest in reading, and, when undertaken with English, where sounds are so capriciously spelt, it seems as if it could hardly be effective. Nor do the Montessori methods in arithmetic reveal anything very different in principle from the "table of units" of Pestalozzi, introduced into America nearly a century ago by Warren Colburn, or from the various objective methods in number work that have been so common ever since. The chief feature in the arithmetical methods of Montessori consists in acquiring the fundamental operations by means of rods of different lengths marked off into sections by coloring them alternately red and blue. This apparatus, known as "the long stair," was originally used for part of the visual training, and seems to have been conveniently at hand when Montessori found it necessary to start number work. After the child has learned to count the sections, the teacher selects a rod at random and asks for the next longer or shorter, or has the child build up all the rods until each result equals the longest. When the numbers from one to ten are fully understood in the concrete, the abstract conception is taught by placing the figures against the corresponding sections. Other exercises are similarly performed until the child has some command of elementary arithmetic.

The value of the Montessori system to modern educational theory and methods should now be fairly obvious. It is at least nominally based upon scientific experiment, and, while its biological statements can not always be accepted without modification, it is permeated with the scientific spirit that is animating modern education. Its emphasis upon individual liberty is most admirable, but the material for exercising this freedom is decidedly limited and social cooperation is somewhat neglected. The exercises in practical activities form a valuable, though not altogther original, feature, and the devices for acquiring writing are possibly a contribution. The importance of the sense training for normal children is probably not as great as Montessori supposes, and the psychological theory upon which it is based has been largely discredited. The devices for teaching reading and arithmetic contain no really new principle, and are not markedly superior to the methods practised for many years by progressive teachers. Clearly, however, while Montessori is neither the tremendous innovator nor "wonder-worker" she has been represented to be, her method is not merely the latest fad. Her indebtedness to the past and the comparative worth of her system are fairly evident to one acquainted with the history of edu-

cation, but it would also seem that she is in harmony with modern progress and has made some contribution to educational practise. Just how large this contribution will be, we can not yet say. Montessori herself is still experimenting both with children of the age with which she began and with older pupils, and schools on a purely Montessori basis or in combination with Froebelian or other methods are springing up everywhere and are likely to obtain illuminating results. It is possible that a new method may yet arise for the lowest classes in our schools, which will combine the best characteristics of both the Froebelian and the Montessorian pedagogy. At any rate, the existence of either as a system, cult or propaganda should end, and both should be based upon and merged with the wider and more dynamic principles of modern educational practise. The Montessori method can be accounted a fad only when half-baked devotees treat it as something that has leaped full-panoplied from the divine head and prostrate themselves before it in blind worship.

THE PROGRESS OF SCIENCE

RUTHERFORD ON THE CONSTITUTION OF MATTER

THE most notable features of the annual meeting of the National Academy of Sciences held in Washington in the third week of April were two lectures by Sir Ernest Rutherford, the distinguished physicist of the University of Manchester. These are the first of a series of lectures, established by the children of William Ellery Hale, which are to treat problems of evolution from the atom to man. At the autumn meeting of the academy, stellar evolution will be reviewed by Dr. W. W. Campbell, director of the Lick Observatory. Sir Ernest's lectures, which were reported stenographically, will be printed in *Science* and ultimately in a book with the other lectures of the series. It is almost impossible to represent their contents by an abstract, but in view of the great interest and importance of the subject and the originality of some of the experiments and theories, it may be well to attempt to give an outline.

Sir Ernest began by reminding his audience that the idea that matter is composed of very minute discrete particles incapable of subdivision and therefore called atoms was familiar to the Greeks, atom in their language being equivalent to the indivisible. This idea was little developed until the beginning of the last century when Dalton first applied it to the chemical constitution of compounds showing that each separate element such as oxygen, iron, nitrogen, etc., always combines in a certain definite equivalent proportion. This is in fact the basal conception of modern chemistry and renders it possible to derive the composition of a substance from a chemical analysis. Chemistry thus lent exceedingly strong support to the hypothesis of the atomic constitution of matter, but no further advance in the subject was made till about the middle of the century when the so-called kinetic theory of gases was developed by Clausius and Maxwell. This theory accounts for the pressure and other properties of gases by supposing them constituted of single atoms, or of small groups of atoms united into molecules, moving with an amount of energy which is proportional to the temperature. The mathematical developments of this theory and the conclusions to be drawn from the formulæ have been verified in cases so very numerous that no one now or for a long time has doubted the essential correctness of the underlying hypothesis. In spite of the conviction that the kinetic theory was true, it was for long supposed that no actual demonstration of atomic or molecular structure could ever be reached. Of late years, however, the study of an almost forgotten phenomenon called the Brownian movement has led to actual demonstrations. Brown as long ago as 1827 observed that microscopic spores of plants suspended in a liquid were in constant motion. The smaller the particles the more actively they were displaced while their movements were thoroughly irregular, the spores passing one another in opposite directions or intersecting one another's paths without any general drift such as would have resulted from ordinary currents in the fluids due, for example, to differences of temperature. Of late years this Brownian movement has been studied with great precision by M. Perrin and others. It has been established that particles sufficiently small, say one ten-thousandth of an inch in diameter, are really displaced in a random manner by the vastly smaller invisible molecules of the fluid in which they are suspended, and that the movements of the mole-

cules can be directly inferred from those of the Brownian particles.

Much more spectacular is the evidence afforded by the cathode rays developed in Crooke's tubes. In these tubes there is emitted from the cathode a stream of luminosity which has very remarkable properties especially that of being deflected by a magnet. This shows that the luminous ray is composed of material particles in motion and charged with electricity. Just to what extent these particles consist of ordinary matter and in how far merely of the electric charge is more or less problematical, but many physicists consider the moving entities as atoms of electricity and this also appears to be Sir Ernest Rutherford's view. These particles are now usually called electrons and they have been identified with the so-called beta rays emitted by radioactive products.

Radium results from the degeneration of uranium, though there are intermediate products, and radium itself likewise gives rise to a series of radioactive products differing from one another. In each of these cases of degeneration, the process is similar. Radium decomposes with the emission of two sorts of rays called the alpha rays and the beta rays. The alpha rays are neither more nor less than atoms of the gas helium, long since known to exist in the sum by its spectrum, and more recently detected in a uranium ore. The beta particles are identical with the electrons which form the cathode rays. The alpha particles are expelled from the radium at a tremendous velocity, but this is far exceeded by the velocity of the beta rays. Sir Ernest Rutherford and his colleagues in radiological investigation have succeeded not only in determining the identity of the alpha particles with helium, but also in establishing the relative size of the electrons and the atoms of helium. The mass of the beta particles is only about one seven-thousandth part the size of the helium atom, and most of the heating effect of radium is due to the energy of the larger alpha particles.

So far has the analysis of these products progressed, and so delicate is the apparatus devised for the study, that Rutherford and Geiger have actually succeeded in making either alpha or beta particles one by one give rise to electrical discharges and light in such a way that the number of either kind of particles emitted per second from a given mass of radioactive matter can be counted. The most efficient apparatus for this purpose is called the string electrometer, so designed as to give a record consisting of small notches on a continuous line. It is like the record of a chronograph and in fact the instrument may be considered as a chronograph. Of this record the notches produced by the alpha particles greatly exceed in depth those given by the beta particles, and thus the rate at which each is given off can be studied with the utmost accuracy on a permanent record.

In a popular description of this kind it is difficult to convey an idea of the extraordinary sensitiveness of the apparatus devised, and none at all of the genius which was requisite to its development, but perhaps enough has been said to show that the most carefully hidden secrets of the ultra-microscopic structure of matter are now subject to scrutiny, and that before long many of its features will be fairly well understood. Sir Ernest concluded his lecture by an illustration of the number of atoms contained in a cubic centimeter of helium. It was something like this. If one hundred million people were to undertake to count these atoms, each person enumerating four per second day and night, the tale would be complete in a couple of thousand years.

THE STRUCTURE OF THE ATOM

Sir Ernest Rutherford's second lecture dealt with the problems of the structure of the atom and the bearings of recent researches on this subject. The lecture was most eloquent and left the audience in a condition of the greatest enthusiasm which they testified by

$10^8 \cdot 86400 \cdot 365 \cdot 4 \cdot 2000$

$= 200 \cdot 10^8 \cdot 10^4 \cdot 10^2 \cdot 10^3$

atomic

rising to give a hearty vote of thanks to the lecturer.

The speaker began by enumerating some of the better known properties of radium and the radioactive products, such as the rate of decay of these substances, ranging from five thousand million years for the half period of uranium down to a few minutes for some of its descendants. He mentioned also the enormous energy of radioactive disintegration, showing that one pound of a radioactive product, if one could gather so much, has the explosive energy of ten million pounds of nitroglycerin. He dwelt also upon the experimental methods developed by Mr. P. T. R. Wilson by which the expulsion of alpha particles and beta particles can be made visible and even photographed. The first part of the path of the alpha particles is nearly straight, but as they lose energy, contact with molecules of other substances deflects them in a characteristic manner. The beta particles, on account of their greatly inferior mass, pursue very irregular courses.

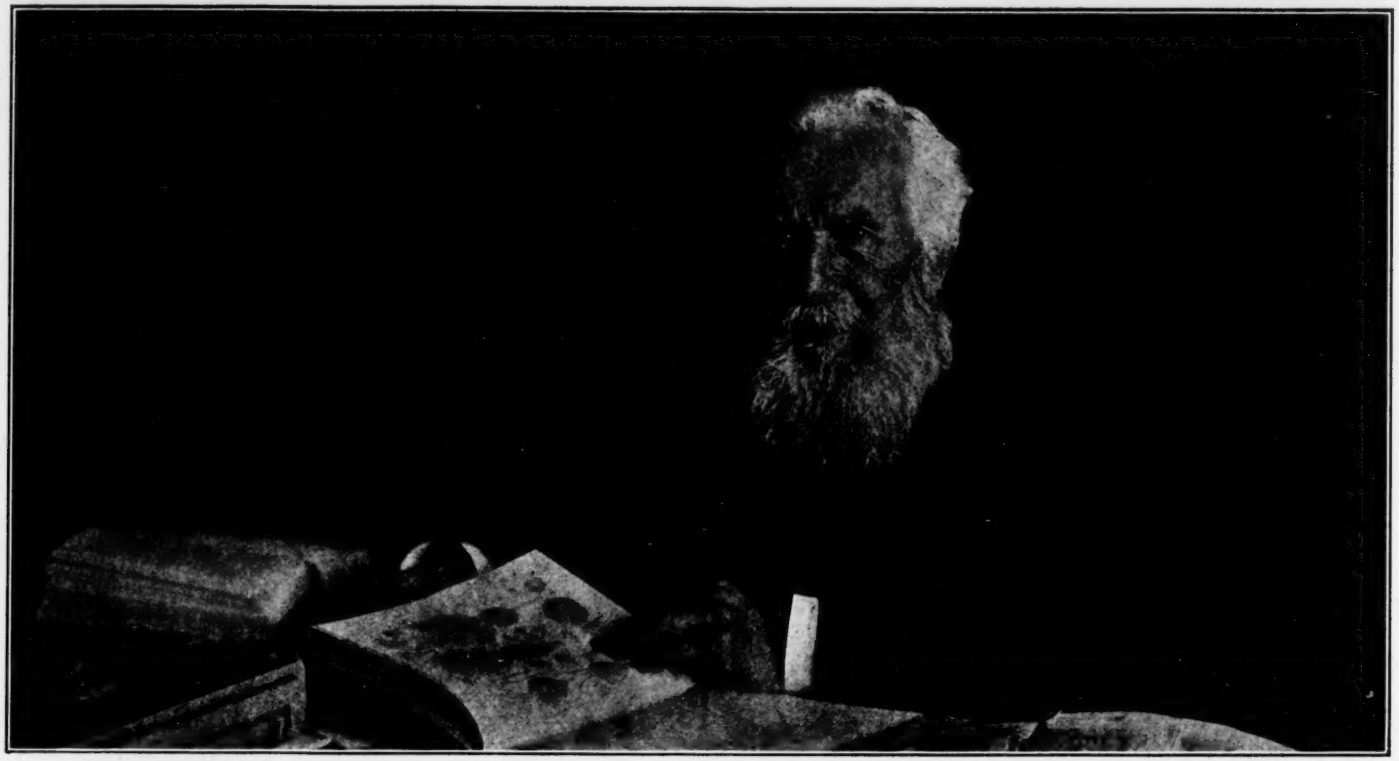
Less well known are the results obtained by Moseley on the interference spectra of X-rays produced by reflection from crystals, especially that of rock salt. These spectra are capable of being photographed and are vastly more simple and more regular than those obtained from visible light. These spectra evince a regularity among the elements which does not appear in the more familiar light spectra, and these regularities tend to elucidate the nature of the atom.

Lord Kelvin conceived an atom as composed of negative electrons included within a space charged with positive electricity holding the electrons together in a single body. This, however, appears to be inconsistent with the researches of Rutherford, who has developed a theory of nuclear atoms, according to which a central nucleus of extremely high potential is surrounded by negative electrons whose motion it controls. If so, the electrons are controlled by the nucleus very much as the planets are held to the solar system by gravitation, and indeed there appears strong reason to suppose that the force involved is really inversely proportional to the square of the distance as in the case of gravitation. From this point of view, the various elements are characterized by the number of electrons in the atom. Each electron carries a single negative charge, and the nucleus carries as many positive charges as there are electrons to be controlled. This theory of the atomic constitution explains the irregularity in the movement of alpha particles through a gas. When an alpha particle approaches a nucleus carrying a charge of millions of volts, it is sharply deflected and may appear even to rebound in the direction from which it came. Sir Ernest illustrated this by a fine experiment. Similarly, if there were a small hole drilled through the center of the earth, a ball dropped from the surface would go straight down and come straight back almost as if it had been infinitely elastic and rebounded from an impenetrable surface.

It is posible to determine the number of positive charges contained in each one of the elements from hydrogen to uranium, and it seems also that if the elements are appropriately arranged the charges increase by unit steps, so that hydrogen contains a single positive charge and uranium 92. This assumption corresponds to the actual elements with a small but very important exception. In the series of 92 possible charges, there are just three gaps, corresponding, presumably, to three unknown elements, and at the same time the relationship of these unknown elements to the known elements is made clear, so that the chemists have preliminary information to guide them in the search for the missing links. This is a wonderful advance on the periodic system of Mendeléef which has itself been fruitful in the discovery of elements.

THE SMALL COLLEGE AND ITS PRESIDENT

THE writer of the article on "The Small College and its President" which appeared in the May number of



PROFESSSOR ERNST HAECKEL

The distinguished professor of zoology of the university at Jena whose eightieth birthday has been widely celebrated.

THE POPULAR SCIENCE MONTHLY writes to the editor to the effect that certain college teachers have professed to be able to find a personal application in the article in question. It has been charged that the picture of "our college" represents a certain trans-Mississipi institution, and that, concealed in the article, are various allusions to particular persons connected therewith. In order to correct this very serious misconception, the writer desires to make the following statement:

The institution referred to as "our college" is purely imaginary, or to speak more correctly, it is a composite picture intended to represent the typical American small college. It is doubtless true that the adherents of any particular college can find in the description details which fit their institution. Were this not the case the article would fail of its purpose as a composite portrait of all the colleges; but it will be found impossible to fit the entire description to any particular college, and it certainly was no particular college that the writer had in mind.

In his description of the size of the college, its faculty, the town in which it is located, its buildings, etc., the writer spoke entirely at random, and tried to picture what may fairly be regarded as average conditions. Since the resulting criticism has been brought to his attention, he has tried to fit the description to a particular college, but without success. He finds, however, that there are some three or four middle-west colleges which, if dismembered and patched together again in the proper pattern might make an institution which would fit pretty well for "our college." The description of the conditions in "our college" are, he believes, typical of the American small college, taking the best with the worst and averaging them, and he has arrived at this conclusion after wide reading in which the valuable reports of the Carnegie Foundation have not been neglected. The reference to the innocuous professor whose beautiful character compensated for the absence of scholarship was intended to represent a not unfamiliar type (at least in some of the older colleges) though the writer will plead guilty to being strongly reminded, while writing it, of the former incumbent of the chair of Latin in a certain eastern college. The incident of the professor who was criticized by one of the trustees for "inefficiency" because he staid at home and attended to his business, was related to the writer about ten years ago, and concerns a college which, so far as he is concerned, shall remain nameless. Suffice it to say that, so far as he has yet learned, nobody has suspected that the article refers in any way to that particular college. The writer does not even know the names of the principals in the case. These few instances will indicate the imaginary and composite character of "our college." It was represented as being on the Carnegie Foundation lest the foundation colleges, reading the article, point their finger at the outside institutions and say: "This is intended for *you!*" The evils incident to what the writer regards as a defective system of college organization affect the foundation colleges equally with the others, though the standard of the foundation colleges of course averages much higher. In fact these evils are not unknown in the universities, but there the problem is much complicated by other factors, and should for that reason be separately considered.

Least of all was it the intention to utter any criticism either on the president or trustees of the small college. The description of the president of "our college" is not a portrait, and the same is true of the trustees. Trustees, president and faculty, are alike victims of what the writer believes to be a defective system, and of the three the president is perhaps most to be pitied. Too often does he find himself in the position of being ground between the upper and the nether millstone. The trustees, as the writer knows them in more than one college, are high-minded, disinterested men, serving without recompense and often with a high degree of self-sacrifice. If anything was made clear in the article in question it was this: that any criticism either of president or trustees was directed not at individuals but at a *system* which demands impossible tasks of both.

SCIENTIFIC ITEMS

WE regret to record the deaths of Dr. George William Hill, distinguished for his contributions to mathematical astronomy; of Dr. Charles Santiago Sanders Peirce, known for his work in logic and mathematics; of Professor Newton Horace Winchell, formerly state geologist of Minnesota, and of Professor Eduard Suess, the eminent Austrian geologist.

DR. W. W. KEEN, of Philadelphia, has been elected president of the Fifth International Congress of Surgeons to be held in Paris in 1917.—The Willard Gibbs medal of the Chicago section of the American Chemical Society has been presented to Dr. Ira Remsen, of the Johns Hopkins University.—Former students of Professor John Henry Comstock have raised a fund, to be known as the Comstock Memorial Library Fund, which is to be presented to Cornell University for a permanent memorial of Professor Comstock's forty years of distinguished service as instructor and professor of entomology.

THE National Academy of Sciences at its annual meeting on April 22 presented its "medals for eminence in the application of science to the public welfare," to Colonel George Washington Goethals and Brigadier General William Crawford Gorgas. The presentation was made by Dr. William H. Welch, president of the academy, at a dinner held in honor of the retiring president, Dr. Ira Remsen, and the retiring home secretary, Dr. Arnold Hague.

MEMBERS of the National Academy of Sciences were elected at the annual meeting as follows: Ernest Merritt, physicist, Cornell University; Moses Gomberg, chemist, University of Michigan; Edward Curtis Franklin, chemist, Stanford University; Frederick Leslie Ransome, geologist, U. S. Geological Survey; Nathaniel Lord Britton; botanist, New York Botanical Garden; Henry Herbert Donaldson, neurologist, Wistar Institute of Anatomy; Herbert Spencer Jennings, zoologist, The Johns Hopkins University; Francis Gano Benedict, chemist, nutrition laboratory of the Carnegie Institution; Walter Bradford Cannon, physiologist, Harvard University; Jesse Walter Fewkes, ethnologist, Bureau of American Ethnology.

AT its annual meeting in Philadelphia the American Philosophical Society elected to membership the following residents of the United States: Charles Greeley Abbot, Washington; James Wilson Bright, Baltimore; Bradley Moore Davis, Philadelphia; Thomas McCrae, Philadelphia; William Diller Matthew, New York; Alfred Goldsborough Mayer, Washington; Samuel Jones Meltzer, New York; John Campbell Merriam, Berkeley; Robert Andrews Millikan, Chicago; William Albert Noyes, Urbana; Stewart Paton, Princeton; Richard Mills Pearce, Philadelphia; Palmer Chamberlaine Ricketts, Troy; Harold A. Wilson, Houston; Frederick Eugene Wright, Washington. Foreign residents were elected as follows: Shibasaburo Kitasato, Tokyo; Heike Kamerlingh Onnes, Leyden; Vito Volterra, Rome.

INDEX

NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS

Abnormalities in Apple Variation, W. J. YOUNG, 158
Agricultural Population, ARLAND D. WEEKS, 251
Air, Fresh, FREDERIC S. LEE, 313
ALVORD, CLARENCE WALWORTH, The Science of History, 490
American, Association for the Advancement of Science, Atlanta Meeting, 199; Museum of Natural History, 514
Americans, Successful, The Racial Origin of, FREDERICK ADAMS WOODS, 397
Animals, The Hibernation of Certain, WALTER L. HAHN, 147
Apple Variation, Some Abnormalities in, W. J. YOUNG, 158
Automobile and the Public Health, P. G. HEINEMANN, 284

Beethoven, The Physical, JAMES FREDERICK ROGERS, 265
Bernard, Claude, D. WRIGHT WILSON, 567
Binet Scale of Intelligence, A Comparison of White and Colored Children measured by the, JOSIAH MORSE, 75
Biologic Effects of Environic Factors, The Measurement of, D. T. MACDOUGAL, 417
Biologist's Problem, T. D. A. COCKERELL, 71
Birds, Migratory, On the Origin of the Flocking Habit of, C. C. TROWBRIDGE, 209
Blood, Composition of, The Effects of School Life upon the, LEWIS M. TERMAN, 257
Bureau of Standards, Track Scale Testing Equipment, 309

Cancer Research, The Present Status of, LEO LOEB, 17
Capital, and Labor, JOHN J. STEVENSON, 459
Carnegie Institution, Work in Terrestrial Magnetism, 415
Celestial Sphere in a Natural History Museum, 102
Chabaneau: an Early Worker on Platinum, JAS. LEWIS HOWE, 64
Chestnut Tree in North America, The Future of the, ARTHUR H. GRAVES, 551
Claude Bernard, D. WRIGHT WILSON, 567
Clinics, School, The Practical Necessity of, E. H. LEWINSKI-CORWIN, 500
COCKERELL, T. D. A., The Biologist's Problem, 71
College, The Small, and its President, ONE OF ITS PROFESSORS, 449
Colombia, Tropical Nature in, A. S. PEARSE, 290
Coloration, Warning, Darwin and Wallace on, F. H. PIKE, 403
CONKLIN, EDWIN GRANT, Facts and Factors of Development, 521
Country School, and The Rural Opportunity, JOSEPH WOODBURY STROUT, 176

Darwin and Wallace on Sexual Selection and Warning Coloration, F. H. PIKE, 403
Democratic Organization of a State University, JOSEPH K. HART, 91
Development, Facts and Factors of, EDWIN GRANT CONKLIN, 521

EDWARDS, CHARLES LINCOLN, Natureplay, 330
EMERICK, CHARLES F., The Struggle for Equality in the United States, 80, 188, 235, 370, 471, 538
Engineering, Work in, at Harvard University and the Massachusetts Institute of Technology, 307
Environic Factors and their Biologic Effects, The Measurement of, D. T. MACDOUGAL, 417
Equality, The Struggle for, in the United States, CHARLES F. EMERICK, 80, 188, 235, 370, 471, 538
Eugenics, and Euthenics, MAYNARD M. METCALF, 383; The Psychological Limit of, HERBERT ADOLPHUS MILLER, 390

Facts and Factors of Development, EDWIN GRANT CONKLIN, 521
Fertility, Permanent, The Illinois System of, CYRIL G. HOPKINS, 52
FISCHER, LOUIS A., Recent Developments in Weights and Measures in the United States, 345
Flocking Habit of Migratory Birds, On the Origin of the, C. C. TROWBRIDGE, 209
Folk-medicine, Psychotherapy in, ABRAM LIPSKY, 227
Fresh Air, FREDERIC S. LEE, 313

Future of the Chestnut Tree in North America, ARTHUR H. GRAVES, 551

Geological Work, Early, of Thomas Nuttall, CHARLES KEYES, 184
GRAVES, ARTHUR H., The Future of the Chestnut Tree in North America, 551
GRAVES, FRANK PIERREPONT, Is the Montessori Method a Fad?, 609

HAHN, WALTER L., The Hibernation of Certain Animals, 147
HARRIS, J. ARTHUR, Current Progress in the Study of Natural Selection, 128
HART, JOSEPH K., The Democratic Organization of a State University, 91
Harvard University, Work in Engineering, 307
Health, The Effects of School Life upon, LEWIS M. TERMAN, 257
HEINEMANN, P. G., The Automobile and the Public Health, 284
Heredity, The Mechanism of, as indicated by the Inheritance of Linked Characters, T. H. MORGAN, 5
Hibernation of Certain Animals, WALTER L. HAHN, 147
History, Science of, CLARENCE WALWORTH ALVORD, 490
HOPKINS, CYRIL G., The Illinois System of Permanent Fertility, 52
HOWE, JAS. LEWIS, Chabaneau: an Early Worker on Platinum, 64

Illinois System of Permanent Fertility, CYRIL G. HOPKINS, 52
Inheritance of Linked Characters, The Mechanism of Heredity as indicated by the, T. H. MORGAN, 5

KEYES, CHARLES, Early Geological Work of Thomas Nuttall, 184

Labor and Capital, JOHN J. STEVENSON, 459
Laboratory, The Physical, and its Contributions to Civilization, ARTHUR GORDON WEBSTER, 105; of Comparative Pathology of the Zoological Society of Philadelphia, R. W. SHUFELDT, 507
LEE, FREDERIC S., Fresh Air, 313
LEWINSKI-CORWIN, E. H., The Practical Necessity of School Clinics, 500
LILLIE, RALPH S., The General Physico-chemical Conditions of Stimulation in Living Organisms, 579
LIPSKY, ABRAM, Psychotherapy in Folk-medicine, 227
Living Organisms, The General Physico-chemical Conditions of Stimulation in, RALPH S. LILLIE, 579
LOEB, LEO, The Present Status of Cancer Research, 17

MACDOUGAL, D. T., The Measurement of Environic Factors and their Biologic Effects, 417
Magnetism, Terrrestrial, Work of the Carnegie Institution, 415
MARSHALL, WILLIAM, The Theory of Relativity and the New Mechanics, 434
Massachusetts Institute of Technology, Work in Engineering, 307
Measurement of Environic Factors and their Biologic Effects, D. T. MACDOUGAL, 417
Mechanics, The New, and Relativity, WILLIAM MARSHALL, 434
Mechanism of Heredity as indicated by the Inheritance of Linked Characters, T. H. MORGAN, 5
METCALF, MAYNARD M., Eugenics and Euthenics, 383
Medical Profession, Salaried, The Need for a, PAUL L. VOGT, 605
Migratory Birds, On the Origin of the Flocking Habit of, C. C. TROWBRIDGE, 209
MILLER, HERBERT ADOLPHUS, The Psychological Limit of Eugenics, 390
Montessori Method, Is it a Fad?, FRANK PIERREPONT GRAVES, 609
MORGAN, T. H., The Mechanism of Heredity as indicated by the Inheritance of Linked Characters, 5
MORSE, JOSIAH, A Comparison of White and Colored Children measured by the Binet Scale of Intelligence, 75
Mortality Statistics of the United States, 411

Natural, History Museum, A Celestial Sphere in a, 102; Selection, Current Progress in the Study of, J. ARTHUR HARRIS, 128
Nature-play, CHARLES LINCOLN EDWARDS, 330
Need for a Salaried Medical Profession, PAUL L. VOGT, 605
Nervous System, The Origin and Evolution of the, G. H. PARKER, 118
New Mechanics, and the Theory of Relativity, WILLIAM MARSHALL, 434
Newspapers, Science in, J. A. UDDEN, 483
North America, The Future of the Chestnut Tree in, ARTHUR H. GRAVES, 551
Nutritive Processes, The Effects of School Life upon the, LEWIS M. TERMAN, 257
Nuttall, Thomas, Early Geological Work of, CHARLES KEYES, 184

ONE OF ITS PROFESSORS, The Small College and its President, 449
Organisms, Living, The General Physico-chemical Conditions of Stimulation in, RALPH S. LILLIE, 579

PARKER, G. H., The Origin and Evolution of the Nervous System, 118
Pathology, Comparative, The Laboratory of the Zoological Society of Philadelphia, R. W. SHUFELDT, 507
PATRICK, G. T. W., The Psychology of Relaxation, 590
PEARSE, A. S., Tropical Nature in Colombia, 290
Permanent Fertility, The Illinois System of, CYRIL G. HOPKINS, 52
Physical, Laboratory and its Contributions to Civilization, The, ARTHUR GORDON WEBSTER, 105; Beethoven, JAMES FREDERICK ROGERS, 265
Physico-chemical Conditions of Stimulation in Living Organisms, RALPH S. LILLIE, 579
PIKE, F. H., Darwin and Wallace on Sexual Selection and Warning Coloration, 403
Platinum, an Early Worker on, Chabaneau, JAS. LEWIS HOWE, 64
Poetry, and Science, CHARLES W. SUPER, 166
Population, Agricultural, ARLAND D. WEEKS, 251
Psychological Limit of Eugenics, The, HERBERT ADOLPHUS MILLER, 390
Psychology, Science or Technology, E. B. TITCHENER, 39; of Relaxation, G. T. W. PATRICK, 590
Psychotherapy in Folk-medicine, ABRAM LIPSKY, 227
Public Health and the Automobile, P. G. HEINEMANN, 284

Racial Origin of Successful Americans, FREDERICK ADAMS WOODS, 397
Relativity and the New Mechanics, WILLIAM MARSHALL, 434
Relaxation, The Psychology of, G. T. W. PATRICK, 590
Research, Cancer, The Present Status of, LEO LOEB, 17
RITTER, WM. E., The World versus Matter, 271
ROGERS, JAMES FREDERICK, The Physical Beethoven, 265
Royal Society, The Anniversary Meeting of the, 101
Rural Opportunity and the Country School, JOSEPH WOODBURY STROUT, 176

Salaried Medical Profession, The Need for a, PAUL L. VOGT, 605
School, Country, and The Rural Opportunity, JOSEPH WOODBURY STROUT, 176; Life, The Effects upon the Nutritive Processes, Health and the Composition of the Blood, LEWIS M. TERMAN, 257; Clinics, The Practical Necessity of, E. H. LEWINSKI-CORWIN, 500
Science, or Technology, Psychology, E. B. TITCHENER, 39; The Progress of, 101, 199, 307, 411, 514; and Poetry, CHARLES W. SUPER, 166; in Newspapers, J. A. UDDEN, 483; of History, CLARENCE WALWORTH ALVORD, 490
Scientific Items, 104, 208, 312, 416, 520, 616
Selection, Natural, Current Progress in the Study of, J. ARTHUR HARRIS, 128; Sexual, and Warning Coloration, Darwin and Wallace on, F. H. PIKE, 403
SHUFELDT, R. W., The Laboratory of Comparative Pathology of the Zoological Society of Philadelphia, 507
Small College and its President, ONE OF ITS PROFESSORS, 449
State University, The Democratic Organization of a, JOSEPH K. HART, 91
STEVENSON, JOHN J., Labor and Capital, 495
Stimulation in Living Organisms, The General Physico-chemical Conditions of, RALPH S. LILLIE, 579
STROUT, JOSEPH WOODBURY, The Rural Opportunity and the Country School, 176
Successful Americans, The Racial Origin of, FREDERICK ADAMS WOODS, 397
SUPER, CHARLES W., Science and Poetry, 166

Technology, or Science, Psychology, E. B. TITCHENER, 39
TERMAN, LEWIS M., The Effects of School Life upon the Nutritive Processes, Health and the Composition of the Blood, 257
Terrestrial Magnetism, Work of the Carnegie Institution in, 415
TITCHENER, E. B., Psychology: Science or Technology, 39
Track Scale Testing Equipment of the Bureau of Standards, 309
Tropical Nature in Colombia, A. S. PEARSE, 290
TROWBRIDGE, C. C., On the Origin of the Flocking Habit of Migratory Birds, 209

UDDEN, J. A., Science in Newspapers, 483
United States, The Struggle for Equality in the, CHARLES F. EMERICK, 80, 188, 235, 370, 471, 538; Mortality Statistics, 411; Recent Developments in Weights and Measures in the, LOUIS A. FISCHER, 345
University, State, The Democratic Organization of a, JOSEPH K. HART, 91

Variation, Apple, Some Abnormalities in, W. J. YOUNG, 158
VOGT, PAUL L., The Need for a Salaried Medical Profession, 605

Wallace, and Darwin, on Sexual Selection and Warning Coloration, F. H. PIKE, 403
Water, E. P. WIGHTMAN, 218
WEBSTER, ARTHUR GORDON, The Physical Laboratory and its Contributions to Civilization, 105
WEEKS, ARLAND D., The Question of Agricultural Population, 251
Weights and Measures in the United States, Recent Developments in, LOUIS A. FISCHER, 345
White and Colored Children measured by the Binet Scale of Intelligence, A Comparison of, JOSIAH MORSE, 75
WIGHTMAN, E. P., Water, 218
WILSON, D. WRIGHT, Claude Bernard, 567
WOODS, FREDERICK ADAMS, The Racial Origin of Successful Americans, 397
World versus Matter, WM. E. RITTER, 271

YOUNG, W. J., Some Abnormalities in Apple Variations, 158

Zoological Society of Philadelphia, The Laboratory of Comparative Pathology of the, R. W. SHUFELDT, 507

3022

Vol. LXXXIV, No. 6 JUNE, 1914

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CONTENTS

Facts and Factors of Development. Professor Edwin Grant Conklin 521
The Struggle for Equality in the United States. Professor Charles F. Emerick 538
The Future of the Chestnut Tree in North America. Professor Arthur H. Graves 551
Claude Bernard. D. Wright Wilson 567
The General Physico-chemical Conditions of Stimulation in Living Organisms. Professor Ralph S. Lillie 579
The Psychology of Relaxation. Professor G. T. W. Patrick . . 590
The Need for a Salaried Medical Profession. Professor Paul L. Vogt . 605
Is the Montessori Method a Fad? Professor Frank Pierrepont Graves 609
The Progress of Science:
Rutherford on the Constitution of Matter; The Structure of the Atom; The Small College and its President; Scientific Items 615
Index to Volume LXXXIV 621

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CONTENTS

RESEARCH IN MEDICINE. By RICHARD M. PEARCE, M.D., Professor of Research Medicine, The University of Pennsylvania.
Antiquity to 1800; The Efforts of Isolated Investigators.
The Development of Laboratories for the Medical Sciences.
Pasteur and the Era of Bacteriology.
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MEDICINE AND THE UNIVERSITIES. By LEWELLYS F. BARKER, M.B., M.D., LL.D. The Johns Hopkins Univ.

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CERTAIN IDEALS OF MEDICAL EDUCATION. By CHARLES S. MINOT, D.Sc., LL.D., James Stillman Professor of Comparative Anatomy, Harvard University.

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THE RELATION OF RESEARCH TO TEACHING IN MEDICAL SCHOOLS. By W. OPHÜLS, M.D., Stanford University.

THE SCIENCE OF CLINICAL MEDICINE. By S. J. MELTZER, M.D., LL.D., The Rockefeller Institute.

THE PUBLIC AND THE MEDICAL PROFESSION. By JAMES EWING, M.D., Cornell University Medical College.

THE DUTIES AND RESPONSIBILITIES OF TRUSTEES OF PUBLIC MEDICAL INSTITUTIONS. By W. W. KEEN, M.D., PH.D., LL.D., Emeritus Professor of Surgery, Jefferson Medical College.

RESEARCH FOUNDATIONS AND THEIR RELATION TO MEDICINE. By HENRY H. DONALDSON, PH.D., D.Sc., The Wistar Institute of Anatomy.

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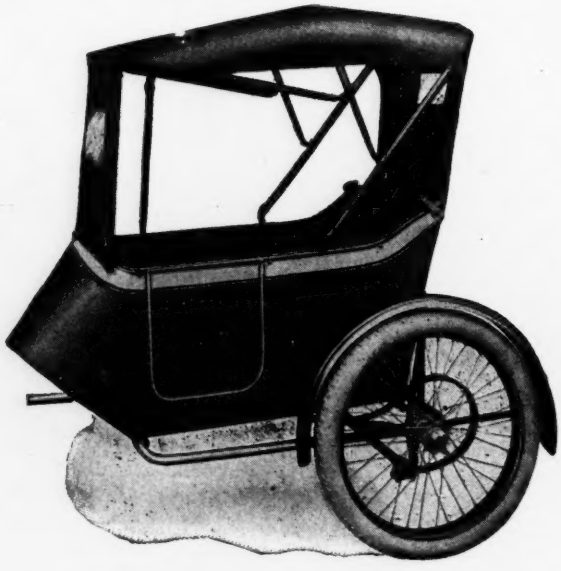

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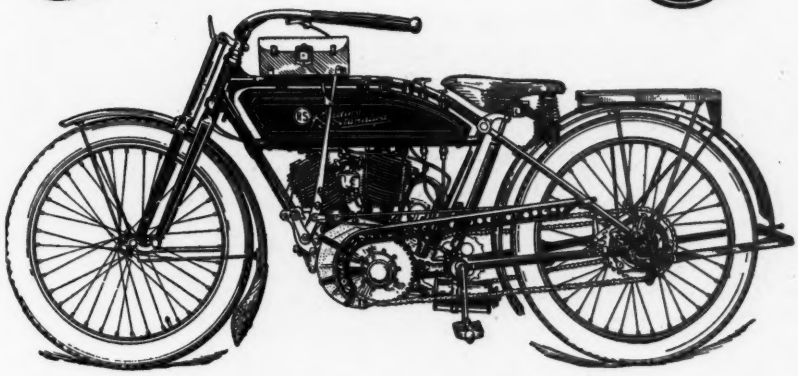

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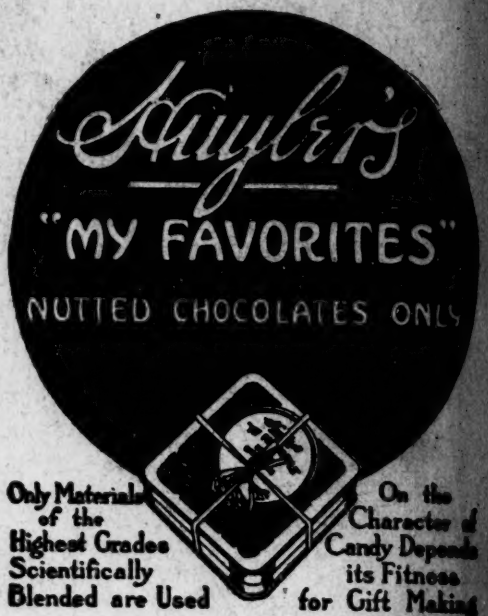

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